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AN AMERICAN TEXT-BOOK OF DISEASES OF THE EYE, EAR, NOSE, AND THROAT

EDITED BY

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PREFACE.

THIS book is offered to students and practitioners of medicine and surgery in general, and to those especially interested in the subjects of which it treats in particular, in the hope that it may take rank with the other volumes of the "American Text-book" series, which have demonstrated their worth and have had their reward in the appreciative reception which has been accorded to them.

In the portion of the work devoted to the Eye, its Embryology, Anatomy, Histology, Physiology, Diseases, and Injuries are discussed in twenty-four sections by twenty-four authors; its Operative Surgery in seven sections by as many authors; while certain practical details in the Examination for Color-blindness among Railroad Employés, etc., receive attention in an Appendix containing five sections.

In the portion of the work devoted to the Ear, its Anatomy, Physiology, Diseases, and Injuries are discussed in thirteen sections by fourteen authors; while Diseases of the Nose and Throat are described in twenty sections by nineteen authors.

Certain novel features, not usually found in text-books, may be noted: Special articles on The Standards of Form and Color-vision Required in Railway Service, The Röntgen Rays in Ophthalmic Surgery, The Practice of Ophthalmic Operations on Animals' Eyes, The Most Important Micro-organisms having Etiological Relationship to Ocular Disorders, etc.

It is unnecessary to discuss the "collaboration-method" thus employed, which has too often demonstrated its value to need either defence or explanation in this place, except to point out its greatest use, and the one to which no doubt it is indebted for its success—namely, that by its means, in the words of Dr. W. H. Howell, "the student gains the point of view of a number of teachers, reaping, in a measure, the same benefit as would be obtained by following courses of instruction under different teachers."

This work is essentially a text-book on the one hand, and, on the other, a volume of reference to which the practitioner may turn and find a series of articles written by men who are authorities on the subjects portrayed by them. Therefore the practical side of the question has been brought into prominence—*i. e.* Functional Testing, Etiology, Symptomatology, Diagnosis, and Treatment, but never to the neglect of Pathology or the important facts comprised in the special chapters on Embryology, Anatomy, Physiology, Physiological

Optics, etc., to which, indeed, special attention is directed. Thus it is hoped that the student will receive not only the point of view of a number of teachers, but a number of points of view of each subject.

A word should be said with reference to the effort to comprise within one volume studies of the Eye, Ear, Nose, and Throat—an effort which may challenge criticism in this day of highly differentiated specialties. Yet it has seemed to the Editors that each of these branches could receive text-book treatment within the space here assigned, while their important correlations could be better brought out by such juxtaposition. Specialism has often been carried much too far in the exclusion of attention to the adjacent fields. The oculist cannot dispense with a fair working knowledge of affections of the nose and its accessory cavities; nor should the aurist have to learn at second hand the important teachings of the ophthalmoscope as to his cases. Indeed, no practitioner, general or special, should be unfamiliar with all the types of disease and the most precise methods of their study, for it must often happen that he cannot avail himself of help from others. He should, like Brougham's educated man, "know a little of everything and all about some one thing." The latter part, as to the specialties here treated, the reader must seek in more voluminous encyclopedic works; but it is hoped that the labors of the eminent teachers here brought shoulder to shoulder will afford a good introduction for the beginner, as before stated, a valuable handy reference-book for the practitioner, and at least quicken some weakening memories in the advanced specialist.

Each author is responsible for the statements and opinions in his article; occasional editorial comment is always suitably marked. For the most part, wherever the same subject receives consideration in different articles, cross references have been supplied, again with the idea of facilitating a study of the point of view. It seems proper to note that there has been complete division of the editorial labor and responsibility, that of the Ophthalmic portion being assumed by Dr. de Schweinitz, and that of the Otological and Laryngological sections by Dr. Randall.

We have to note and deplore the loss to ourselves and to the profession in the death, during the preparation of this work, of Dr. Harrison Allen, robbing us of his finishing touches to his own contribution and the continuance of his friendly counsel as to other portions of the book. Of the greater loss in his many fields of activity we cannot here speak.

In conclusion, the Editors desire to express their hearty thanks to all the contributors for their uniform courtesy and for the presentation of the subjects entrusted to them in a manner which, they feel sure, cannot fail to be satisfactory to students. Also, their thanks are due to Mr. T. F. Dagney and Mr. R. W. Greene for their efficient aid and constant kindness.

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February, 1899.

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THE EYE.

THE EYE.

THE EMBRYOLOGY, ANATOMY, AND HISTOLOGY OF THE EYE.

BY GEORGE A. PIERSOL, M. D.,
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THE DEVELOPMENT OF THE EYE.

THE initial stages in the formation of the visual organ are so intimately related to those of the brain, that a brief sketch of the early development of the nervous system may with advantage precede the more detailed account of the development of the eye.

The first definite trace of the embryo within the embryonal area appears as a pair of slightly converging folds, the *medullary plates*, which partially

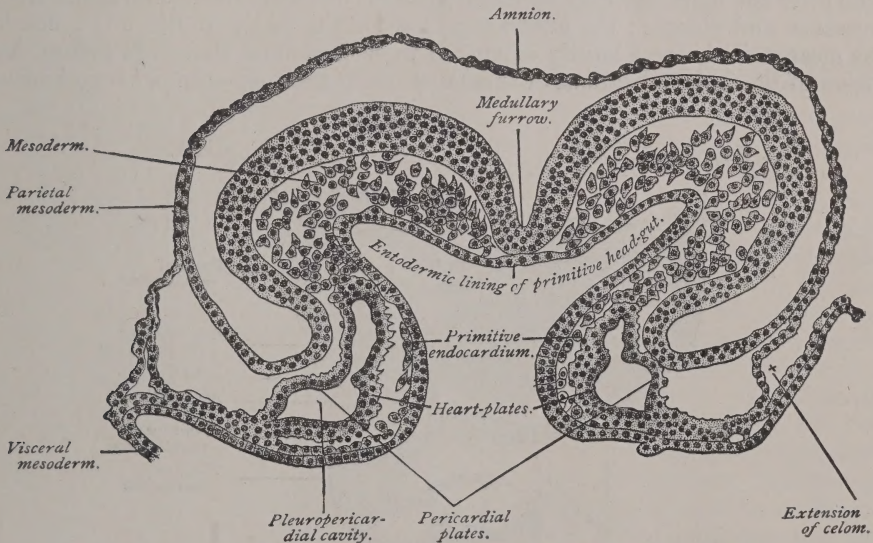


FIG. 1.—Transverse section of a sixteen-and-a-half-day sheep embryo (Bonnet).

enclose the anterior end of the transient primitive streak. Originally widely separated and low, the folds rapidly increase in height, while the included *neural groove* becomes correspondingly deepened (Fig. 1). Very soon the growing medullary plates manifest a tendency to approximate their free edges along the dorsal aspect of the embryo, a disposition which eventually results in their fusion and the conversion of the open neural groove into the closed

neural canal (Figs. 2 and 3). The point at which this fusion earliest occurs does not coincide with the anterior extremity of the canal, but with a point somewhat farther back; from this latter situation closure progresses toward the caudal pole.

The anterior extremities of the medullary folds remain ununited for some

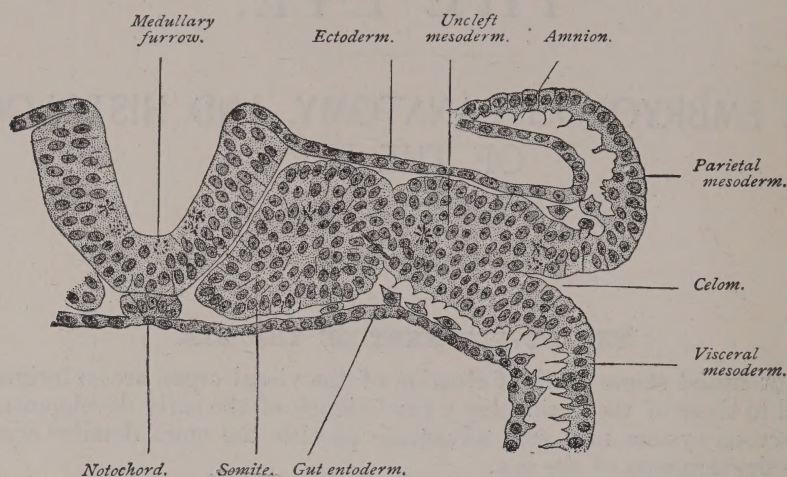


FIG. 2.—Transverse section of a sixteen-and-a-half-day sheep embryo possessing six somites (Bonnet).

time after the more caudally situated parts of the folds have undergone concrescence and closure; the anterior portion of the folds, on the other hand, has meanwhile become locally expanded in such manner that even before the fusion of the folds indications of three distinct dilatations—the *primary brain-*

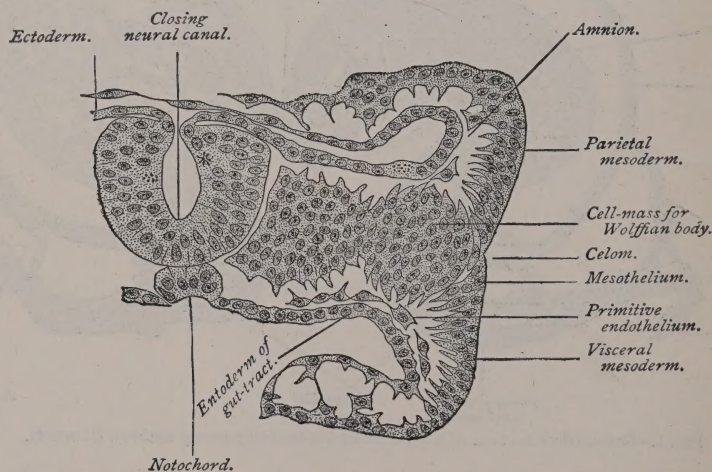


FIG. 3.—Transverse section of a fifteen-and-a-half-day sheep embryo possessing seven somites (Bonnet).

vesicles—have become apparent. The foremost of these, the *anterior brain-sac*, occupies the extreme end of the neural canal, and is of large size, the succeeding *middle* and *posterior* vesicles being less expanded, although of greater length.

The primary cerebral vesicles, however, soon undergo further change, since the anterior and the posterior each become subdivided, the cephalic

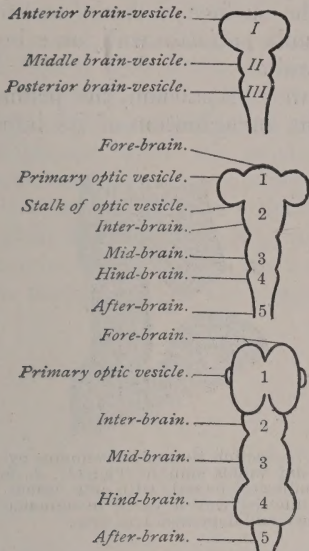


FIG. 4.—Diagrams illustrating the primary and secondary segmentation of the brain-tube (Bonnet).

segment of the neural tube being then represented by the five *secondary brain-vesicles*. These latter are designated, from before backward, as the *fore-brain*, or *prosencephalon*; the *inter-brain*, or *thalamencephalon*; the *mid-brain*, or *mesencephalon*; the *hind-brain*, or *epencephalon*; and the *after-brain*, or *metencephalon* (Figs. 4

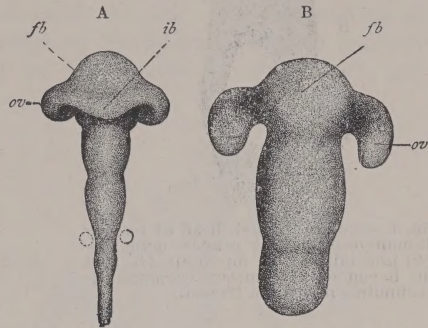


FIG. 5.—A, brain of two-day chick embryo; B, brain of human embryo of three weeks (His); shows the development of the optic vesicles and brain-vesicles; fb, fore brain; ib, inter-brain; ov, optic vesicle.

and 5). The remains of the greatly modified and relatively reduced cavities of these early brain-segments are represented respectively by the lateral ventricles, the third ventricle, the aqueduct of Sylvius, and the fourth ventricle; while from the walls of the secondary brain-vesicles are developed the structures situated around the corresponding part of the ventricular space.

Coincidentally with the development of the primary cerebral vesicles, even before the complete closure of the neural canal, the anterior brain-sac becomes distinguished by the evagination of a conspicuous diverticulum on either side, which extends almost at right angles to the general cerebral axis. These outgrowths from the hinder part of the early anterior cerebral segment are the *primary optic vesicles*, from which the nervous tunic of the eye is largely developed. The optic vesicle at first opens so widely into the brain-sac that there is little differentiation of the ocular rudiment from the general cavity of the brain-segment; soon, however, the communication between the two becomes narrowed and the optic vesicle better defined as an independent organ. The *optic stalk*, which results from this constriction, lies almost transversely placed when first formed, but gradually assumes a more oblique axis as its development progresses. The relations of the optic stalks to the brain-segments also somewhat change, since when definitely formed the stalks open into the inter-brain, or thalamencephalon, having seemingly become posteriorly removed during their growth.

In attaining its full expansion the primary optic vesicle has encroached to such an extent on the mesoderm lying between the eye-sac and the surface of the embryo, that in mammals an extremely thin stratum of mesodermic tissue alone separates the optic vesicle from the surface ectoderm: in birds even this is wanting, the mesoderm being entirely displaced and the ectoderm

of the exterior and anterior wall of the optic vesicle coming into apposition (Fig. 6).

Each optic vesicle may be regarded as possessing four walls—a *lateral* or outer wall, including the area in apposition to the surface; a *mesial* or inner wall, marked by the position of the early optic stalk; a *lower* wall, on a level with the floor of the inter-brain; and an *upper* wall.

After meeting the surface layers in its outward expansion, the primary optic vesicle becomes profoundly modified by the invagination of its lateral

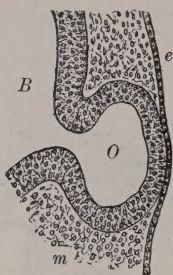


FIG. 6.—Section through head of ten-day rabbit embryo, exhibiting primary optic vesicle (O) protruding from fore-brain (B), and coming in contact with surface ectoderm (e); m, surrounding mesoderm (Piersol).

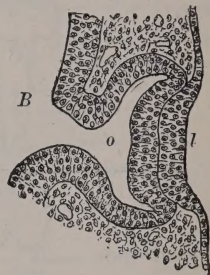


FIG. 7.—Section through developing eye of eleven-day rabbit embryo (Piersol): B, fore-brain connected by stalk with optic vesicle (o), whose anterior wall is partly invaginated; l, thickened and depressed lens area.

or outer wall, in consequence of which pushing in, the cavity of the primary vesicle is gradually reduced, and, finally, obliterated by the application of the invaginated portion of the wall of the vesicle to the mesial segment of the same, which has not suffered displacement. The space which results from the invagination of the outer portion of the primary eye-sac gradually acquires a cupped form, and is known as the *secondary optic vesicle*, or, more appropriately, as the *optic cup* (Figs. 7 and 8).

Coincidentally with the changes in the optic vesicle which result in the production of the optic cup, the ectoderm lying over the optic vesicle exhibits

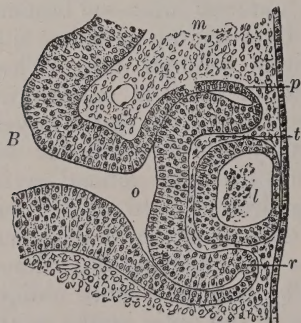


FIG. 8.—Section through developing eye of eleven-and-a-half-day rabbit embryo (Piersol): B, fore-brain connected with optic vesicle (o), nearly effaced by apposition of invaginated anterior segment (r) with posterior wall (p); l, lens-sac completely closed and separated from ectoderm; t, tissue within secondary optic cup derived from surrounding mesoderm.

proliferation of its elements and becomes thickened, and, at the same time, sinks into the subjacent invaginating optic vesicle, thus forming a depression known as the *lens-pit*. The thickened ectoderm lining the bottom and sides of the pit is accurately applied to the receding lateral wall of the optic vesicle, separated in mammals, however, by a thin sheet of mesodermic tissue. The invagination of the early lens-pit increases, and, at the same time, the margins of the depression become approximated and eventually united, so that the lens-pit is converted into the *lens-vesicle*, a structure from which the future crystalline lens is developed in a manner presently to be described. The lens-sac thus formed for a time remains connected with the ectoderm; later, the union between the two is severed, and the primary lens-

rudiment lies as an isolated ectodermic vesicle completely surrounded by mesoderm. The mesodermic stratum which separates the lens-sac from the

overlying ectoderm later contributes the connective-tissue stroma of the cornea, while the corresponding ectodermic area becomes the corneal epithelium (Fig. 8).

Returning to the consideration of the changes involving the optic vesicle, we have to follow modifications which result in the formation of the most important parts of the nervous tunic of the eyeball. As already sketched, the lateral wall of the primary optic vesicle becomes invaginated as the lens-sac is developed: while in the early stages the two invaginations progress with uniform rapidity, there comes a time, after the lens-sac has reached completion, when the expansion of the inner wall of the latter no longer keeps pace with the pushing-in of the optic vesicle, in consequence of which disparity a space, the *primitive vitreous chamber*, appears between the lens-vesicle and the retreating wall of the optic vesicle. The completion of the invagination results in the approximation of the lateral folded-in wall toward the mesial wall of the vesicle, until the two layers are in contact and the

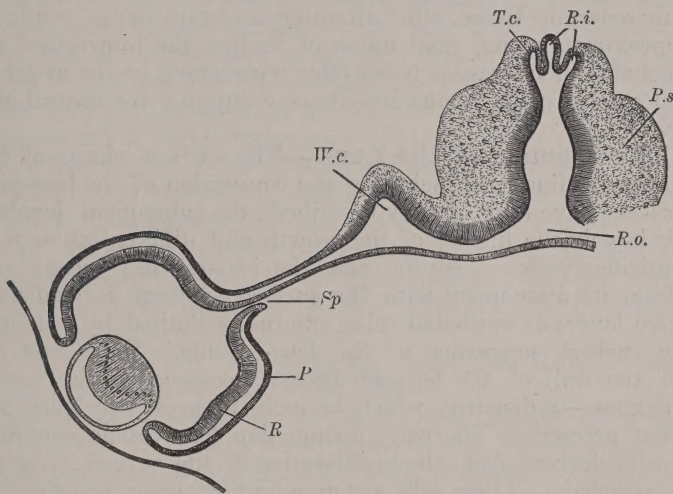


FIG. 9.—Section through the optic vesicle, the optic stalk and adjoining parts of the cerebral vesicle of a five-weeks' human fetus (His): *R*, *P*, retinal and pigment layers of optic vesicle; *S.p.*, cleft for entrance of central artery; *T.c.*, tuber cinereum, with recessus infundibuli (*R.i.*); *W.c.*, basal conus; *R.o.*, recessus opticus. The lower part of the figure corresponds to the nasal side, the upper to the temporal.

included cavity of the primary optic vesicle is obliterated. The secondary vesicle, or the *optic cup*, is now bounded by a double-layered wall.

Almost from the beginning of the process of involution involving the primary optic vesicle the portion of the wall of the sac so affected exhibits a disposition to undergo proliferation and thickening, in consequence of which change the developing optic cup is immediately bounded by a disproportionately thick stratum, which from the resulting structures is appropriately termed the *retinal layer*. In marked contrast to the inner, the outer layer of the optic cup not only fails to increase in thickness, but becomes attenuated in consequence of the general expansion of the growing primitive visual organ, so that by the time the retinal layer comes in contact with the outer layer of the optic cup, the latter has become reduced to a delicate stratum of cells which would be inconspicuous were it not for its characteristic dark tint due to the presence of rapidly augmenting pigment-particles. The pigmented condition of the cells of the outer layer early foreshadows the subsequent fate of this portion of the optic vesicle, which eventually forms the single layer of pigmented

retinal epithelium. From the thickened inner layer are derived the essential nervous elements of the retina, including the rods and cones, the various ganglion-cells and the nerve-fibers proceeding from them, together with the supporting neuroglial tissue.

The invagination described in the preceding paragraphs as affecting the lateral or outer wall of the primary optic vesicle is not limited to that portion of the eye-sac, but involves also the lower wall of the vesicle and its hollow stalk. Reference to the accompanying figure (9, *Sp*) will show that the lower wall of the double-layered vesicle is not complete, but is pushed in—in frontal sections this inferior groove appearing as a hiatus in the vesicle, the *choroidal cleft*. This latter slit establishes communication between the surrounding mesoderm and the interior of the optic cup, and affords entrance of the mesodermic tissue which constitutes the primary vitreous stroma; it soon becomes greatly narrowed and finally closes.

In consequence of the infolding of its lower wall the optic stalk, at first cylindrical, becomes deeply grooved; the groove, which is occupied by vascular mesodermic tissue, after attaining a certain depth, gradually closes by the approximation and final union of its lips, the imprisoned mesoderm and the included blood-vessels being later represented by the *arteria centralis retinae* and the associated connective tissue occupying the central area of the optic nerve.

The Development of the Lens.—The earliest phases of the formation of the crystalline lens, including the conversion of the lens-pit into the closed lens-sac, have been already described; the subsequent development of the lens is largely the history of the growth and differentiation of the walls of the lenticular vesicle. By the time the lens-sac has become completely isolated from its attachment with the surface ectoderm its walls consist of two or three layers of epithelial cells, externally limited by a delicate membrane, the earliest suggestion of the lens-capsule. Very soon the inner portion of the wall of the lens-sac becomes conspicuous by reason of its greater thickness—a disparity which becomes progressively more marked as development proceeds. The early mammalian lens-vesicle contains a mass of small cells derived from the proliferation of the surface elements of the primitive epidermis. These cells are unimportant, being transient, and later undergoing degeneration and absorption.

The obliteration of the cavity of the lens-sac and the conversion of the organ into a solid mass are effected by the phenomenal growth and elongation of the epithelial elements composing the posterior or internal wall of the sac. These cells rapidly increase in length, becoming converted into the primitive lens-fibers. At first the thickened inner wall projects into the lens-vesicle, the greatly reduced cavity of the sac intervening between it and the anterior wall. With the growth of the fiber-mass this space is gradually reduced, until finally the now greatly thickened and specialized posterior wall comes into contact with the anterior layer and the lens becomes solid.

The thickening and growth which have characterized the changes affecting the posterior or inner wall of the lens-sac are in marked contrast to the progressive attenuation of the anterior or outer wall. The columnar type of the early cells of this region is replaced by the low cuboidal form which characterizes these elements in later stages.

After the primitive lens becomes solid in consequence of the obliteration of the cavity of the lens-vesicle by the growth and modification of the posterior wall, the subsequent increase in the size of the lens takes place by the conversion of the cells of the anterior wall, which are later known as the

epithelium of the anterior capsule, into lens-fibers, and the addition of these as peripheral increments. The transformation of the epithelial cells into fibers takes place at the equatorial zone, where the low columnar elements may be seen elongating and assuming the peculiarities of young fibers. The appositional growth of the lens which thus takes place results in the formation of layers of lens-fibers which cover the surface of the organ and enclose the lens-core. In consequence of their mode of equatorial formation the young fibers extend from the anterior to the posterior surface of the lens, their ends meeting along definite radiating lines which in the embryo and the new-born animal constitute three-rayed figures known as the *lens-stars*. The star of the *anterior* surface always has its superior limb directed vertically, the remaining rays diverging laterally at an angle of 120° . The rays of the *posterior star* are disposed in such manner that they fall between those of the anterior figure, the vertical limit being below and the others extending upward and outward. In the adult lens the figures lose their former simplicity by the appearance of other and secondary rays, the adult lens-stars being indistinct and uncertain in their outlines. The modifications of the stars in the fully-grown lens are largely due to the fact that in the enlarged organ the fibers are no longer capable of spanning the entire distance between the anterior and posterior surfaces, as do the young embryonal fibers.

The *lens-capsule* is early suggested by the appearance of a delicate membrane, which limits the outer surface of the lens-vesicle, and afterward undergoes thickening, becoming apparently homogeneous and of elastic character, which distinguishes this part of the eye. Two opposed views exist regarding the source of the capsule: according to one, the capsule is developed as a secretion from the cells of the lenticular vesicle, while the other regards it—and, the author believes, correctly—as derived from the mesodermic tissue surrounding the primitive lens.

It will be noted from the foregoing description that the entire lens, excluding its capsule, is of ectodermic origin.

The unusual demands made by the young, rapidly-growing and, at the same time, non-vascular lens on surrounding tissues for its nutrition result in the provision of a special, although temporary, structure designed to meet that need. The structure so developed consists of an envelope of vascular mesodermic tissue, the *tunica vasculosa lentis*, which completely surrounds the young lens from the second month to toward the end of gestation, at which latter period it has usually atrophied and disappeared.

The *tunica vasculosa* is closely associated with the vitreous, since its blood-vessels are derived from those of that body. The large vessels over the posterior surface of the lens break up into smaller branches, which, bending around the equator of the lens, ramify within the mesodermic sheet covering the anterior surface, proceeding almost as far as the center of the pupil, where they end in terminal loops. The different parts of the vascular membrane of the lens bear particular names, in consequence of having been first observed at different times. The portion of the membrane opposite the pupil was called the *membrana pupillaris*; the more peripherally situated zone constituted the *membrana capsulo-pupillaris*; while that covering the posterior surface was designated the *membrana capsularis*. It is evident that these are but parts of one and the same vascular sheet which is now appropriately called the *tunica vasculosa lentis*. Usually this structure is best developed at about the seventh month, after which time it undergoes atrophy and absorption, so that at, or even before, birth it has entirely dis-

appeared. Exceptionally, parts of the embryonal structure remain after birth, the anterior portions, when present, constituting the *persistent pupillary membrane*. (See page 331.)

The early infolding of the lower wall of the optic vesicle is closely related to an outgrowth of the surrounding mesoderm, which occupies the invagination, and thus gains entrance into the secondary optic vesicle or optic cup, in which space it rapidly expands until the actively proliferating mesodermic tissue completely fills the space between the primitive lens and the retinal layer of the optic cup. In structure the primary vitreous corresponds to an embryonal form of connective tissue, in which a delicate network of branched connective-tissue elements is conspicuous. At a later stage these cells atrophy, while numerous leukocytes, derived from the ingrowing blood-vessels, invade the vitreous tissue. Coincidentally with the growth of the primitive vitreous an extension of the artery occupying the young optic nerve, which later becomes the *arteria centralis retinae*, takes place, the vessel invading the vitreous passing to the posterior pole of the young lens as the *hyaloid artery*. With the appearance of the latter vessel the vitreous becomes abundantly supplied with capillaries, from which not only the leukocytes already mentioned pass into the proliferating mesoderm, but also the watery constituents which later give to the vitreous tissue its characteristic semi-fluid condition (Fig. 10).

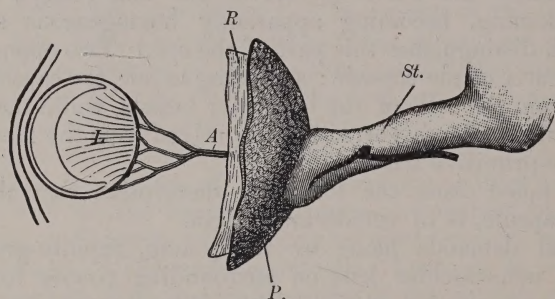


FIG. 10.—Projection from nasal side of the stalk of the optic vesicle and the central artery of the retina (His): L, lens; A, anterior continuation of the central artery to the vascular tunic of the lens; R, P, respectively the nervous and pigment lamella of the optic vesicle; St, optic stalk, with entrance of central artery.

In addition to providing the vitreous tissue with capillaries for its direct nutrition during the early stages of its active growth, the hyaloid artery ramifies within the mesodermic layer covering the posterior surface of the lens, thus first supplying that portion of the tunica vasculosa lentis known as the *membrana capsularis*. From this portion of the lens envelope, as already mentioned, the blood-vessels extend forward, and finally spread out within the anterior segment over the corresponding surface of the lens, to constitute the vessels of the *membrana pupillaris*.

During the last weeks of fetal life the blood-vessels of the vitreous, together with the tunica lentis, disappear, the only indication of this elaborate intraocular vascular network which persists being the remains of the hyaloid artery within a passage, the *hyaloid canal*, which extends from the optic entrance to the posterior pole of the lens. Sometimes, however, the hyaloid artery undergoes less atrophy, and is then represented by a cord which extends toward the lens, and may be provided with a lumen for a portion of its length; in such cases the persistent hyaloid artery may form a conspicuous object when viewed with the ophthalmoscope. (See page 403.)

Development of the Retina.—In the foregoing consideration of the initial changes in the formation of the optic cup the early conspicuous differentiation of the inner and the outer layers composing its walls has been pointed out. By the time the infolded portion of the vesicle has been closely applied to the uninvolved segment, the former, or inner layer, has attained a thickness of many times that of the outer layer: the latter, however, has become conspicuous, notwithstanding its attenuation, by reason of the pigment-granules which early accumulate within its cells. The pigment appears earliest near the anterior margin or lip of the optic cup, gradually extending toward the posterior pole, until the entire outer layer appears uniformly dark. This layer becomes the future *pigmented retinal epithelium* (Fig. 11).

The fate of the greatly thickened inner layer is largely identical with the history of the development of the retina, since it contributes the most important parts of the nervous tunic. The early stages in the development of the retina resemble closely those seen elsewhere in the walls of the young brain-vesicles, active proliferation of the cells lining the neural tube being a conspicuous feature. As in other parts of the young cerebro-spinal tube, the differentiation of the cells constituting the inner layer of the optic cup results in the formation of two varieties of tissues—the nervous elements and the sustentacular tissue.

The differentiation of the nervous constituents results in the formation of two groups of elements—the nerve-cells and their outgrowths, the nerve-fibers, and the retinal neuro-epithelium; the latter eventually becomes specialized as the layer of rods and cones and the outer nuclear layer, these two strata together constituting the layer of *visual cells*, as the sensory epithelium is here appropriately called. The further development of the sustentacular tissue produces the characteristic radial fibers of Müller, which extend throughout the thickness of the retina and afford support and connection to the nervous elements. In addition to the derivatives from the involuted ectoderm, ingrowths of true connective tissue take place from the surrounding mesodermic tissue which accompanies the ramifications of the early *arteria centralis retinae*.

While the developmental changes just described affect the far greater part of the optic cup, the anterior zone, corresponding to the double-layered lips of the cup, differs materially in its growth and fate. Coincidentally with the increase of surface which the general expansion of the developing eye effects, the anterior zone of the optic cup becomes greatly thinned, the inner layer becoming reduced to a single layer of low columnar elements, in marked contrast to the conspicuous thickening which this layer undergoes throughout the posterior segment of the cup.

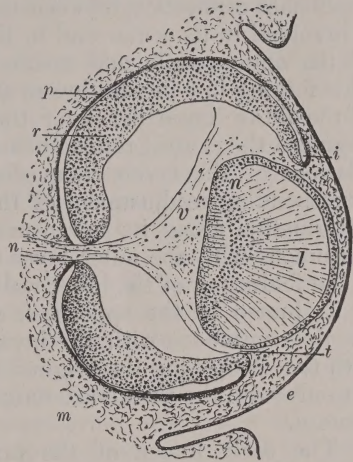


FIG. 11.—Section through developing eye of thirteen-day rabbit embryo (Piersol): *e*, ectoderm; *l*, lens, consisting of anterior nucleated division representing thin front wall of lens-sac, and greatly thickened posterior division completely filling cavity of sac by elongated fibers whose nuclei present crescentic zone (*z*); *p*, posterior pigmented layer; *r*, specialized anterior retinal layer; *i*, point where layers of optic vesicles become continuous; *n*, extreme peripheral section of tissue of primitive optic nerve connected with vascular tunic (*v*), occupying posterior surface of lens; *m*, surrounding mesoderm, which (at *t*) grows between lens and retina.

The extension of the anterior marginal zone of the optic cup is intimately associated with the changes within the surrounding mesoderm, which lead to the development of the structures composing the ciliary region and the iris: the forward growth of the attenuated lips of the cup contributes the double-layered, and later deeply pigmented, epithelial investment covering the inner surface of the ciliary body and the iris as far as the pupil. The *pars ciliaris retinae* and the *pars retinae iridica*, which include the deeply pigmented stratum covering these respective regions, are, therefore, representatives of the anterior zone of the ectodermic optic cup. The line of demarcation between the posterior visual and the anterior rudimentary segments of the optic cup is at first not sharply marked, but later, when the conspicuous differences in the growth of the layers in the two regions become established, the anterior limit of the retinal area gradually becomes well defined at the position later indicated by the *ora serrata*.

Development of the Optic Nerve.—The early optic stalk, which establishes connection between the primary optic vesicle and the inter-brain, is involved in its ocular end in the invagination which affects the lower wall of the optic vesicle and results in the formation of the *choroidal fissure*. This folding-in—in addition to affording a means of entrance into the interior of the future optic nerve for the vascular mesoderm, from which later are produced the central retinal blood-vessels—is rendered necessary by the new relations of the layers composing the walls of the optic cup: without the corresponding readjustment of the walls of the optic stalk, as effected by the invagination along its lower margin, the walls of the stalk-tube would be continuous with the outer layer of the optic vesicle alone. In consequence of the folding-in of the lower wall of the stalk and the subsequent obliteration of its lumen by the apposition of its walls the layers composing the latter remain continuous with the invaginated portion of the optic cup, as well as with that possessing the original relation; hence the connection is maintained not only with the thickened retinal sheet, but also with the attenuated outer stratum.

The early lumen of the primary optic stalk soon disappears, and is replaced by a solid condition of the young optic nerve. This solidification is effected by two processes, one of which affects the greater central part of the stalk as far as its cerebral attachments, while the other, which includes the end applied to the optic vesicle, is limited to the peripheral and smaller segment of the nerve. The greater part of the hollow stalk is converted into a solid cord by the gradual thickening of its walls, due to active proliferation of the elements, which results in the subsequent apposition and final obliteration of the lumen. The solidification of the ocular portion of the stalk is the result of both invagination and proliferation: the early invagination of the lower wall of the stalk when completed effects the closure of the lumen of the tube by the apposition and final fusion of the walls of the tube; while the proliferation of the margins of the furrow results in the approximation and complete closure of the groove, the growth of the so imprisoned mesoderm, together with the accompanying blood-vessels, producing the connective tissue surrounding the central retinal blood-vessels as they occupy the interior of the optic nerve.

The development of the nerve-fibers is a secondary but coincident process, the newly-formed fibers occupying the walls of the rapidly closing stalk. The older views which regarded the optic fibers as being produced *in loco* along the course of the optic stalk are no longer accepted since the investigations of Müller, Kölliker, His, and others showing that the young fibers grow

into the optic stalk from the nerve-cells located at its extremities. The great majority of fibers of the optic nerve may be regarded as the centrally directed outgrowths of the young neuroblasts situated within the developing retina: the axis-cylinder processes of these elements are guided in their journey to form central relations with the brain-centers by the supporting tissue contributed by the optic stalk. In addition, however, to the centrally growing fibers, there are others which pass in the opposite direction, and represent the peripherally directed axis-cylinder processes of the neuroblasts situated within the brain. Further complexity of structure later arises from the ingrowth of the vascular connective tissue constituting the pial sheath of the optic nerve, the extensions of which tissue form the septa subdividing the nerve into the variously sized bundles which are so conspicuous in transverse sections. The posterior parts of the optic stalks become the optic tracts, while their middle portions unite to form the optic chiasm. The sheaths of the optic nerve are produced by the direct continuation of the mesodermic investment from which the cerebral dura, arachnoid, and pia are derived.

Development of the Fibrous and Vascular Coats.—With the exception of the corneal epithelium, the lens, and the nervous tunic with its cerebral attachments, which are derived from the ectoderm, all parts of the eyeball are developed from the mesoderm surrounding the primary optic vesicle. Coincidentally with the changes affecting the optic vesicle, as already noted, the surrounding mesoderm exhibits a differentiation, marked by active cell-proliferation and condensation, which results in the production of a distinct envelope of actively growing embryonal connective tissue. The posterior segment of this mesodermic capsule undergoes further differentiation into an outer, relatively dense tunic, which becomes the sclerotic, and an inner coat, which later is distinguished by a looser texture and greater vascularity.

Very early in the history of the eye the lens-sac is separated from the overlying ectoderm by a thin stratum of mesodermic tissue; later this layer becomes cleft, one part remaining as a thin mesodermic sheet over the outer surface of the young lens, the other adhering to the inner surface of the ectoderm. The strata of mesoderm so formed constitute the pupillary membrane and the substantia propria of the cornea, the intervening cleft being the earliest indication of the future anterior chamber. The forward growth of the thin double-layered lip of the optic cup beyond the equator of the young lens and over its anterior surface is accompanied by a proliferation of the adjacent mesoderm and the extension of the primitive choroidal stratum which accompanies the retinal tissue in its growth forward. This anterior extension of the lip of the optic cup and the associated mesoderm gives rise to the rudiments of the iris and ciliary body, this expansion progressing until almost the entire anterior surface of the lens is covered: the central unoccupied area thus corresponds to a circular aperture within the retino-iridial sheet which remains as the pupil. In the early stages this opening is closed by the vascular pupillary membrane, a temporary structure which disappears before birth.

The active growth of the thin lips of the optic cup results in still greater attenuation of the component strata of epithelial cells until these are represented by the low columnar and cuboidal elements of the pars ciliaris and pars iridica retinae; the pigmentation of these epithelial cells also increases until the anterior portion of both layers is loaded with color-particles and the conspicuous pigment layer covering the posterior surface of the iris is produced. The accompanying mesodermic layer thickens and gives rise to

the stroma and muscular tissue of the iris and ciliary body, and for a time is also continuous with the vascular tunic of the lens.

About the beginning of the third month, in consequence of an unusual active lateral expansion, the epithelial layers are thrown into a series of radial folds which surround the equator of the lens: these plications are the earliest suggestion of the future ciliary processes, and into them shortly afterward delicate processes of mesodermic tissue extend; later these become more robust, and in them the characteristic richly vascular structures of the ciliary processes develop. In contrast to the deep pigmentation involving both epithelial layers of the pars iridica retinæ, only the outer stratum of the pars ciliaris contains pigment, the elements of the inner layer remaining uncolored and retaining to a greater extent their original columnar form.

The corneal stroma becomes blended with that of the sclerotic tunic, so that eventually the two become continuous. With the formation of the anterior chamber the mesodermic elements immediately in contact with the lymph-space differentiate into flattened cells which become the posterior endothelium of the cornea and the anterior endothelium of the iris. The formation of the spaces of Fontana and of the trabeculæ of the ligamentum pectinatum iridis is closely associated with the differentiation of the anterior extremity of the primitive choroidal tract and the production of the membrane of Descemet; to this tract the name *pars uvealis corneæ* has been applied.

Development of the Vitreous Body.—This is intimately related with the primary changes of the optic vesicle. As already described, the invagination of the latter sac involves not only the external portion directed toward the surface, but affects likewise its inferior wall, resulting in the production of the choroidal fissure, which leads from the exterior into the cavity of the secondary optic vesicle. The surrounding mesoderm takes advantage of the cleft so established to gain entrance into the interior of the optic cup, which soon becomes filled with an extremely delicate mesodermic tissue occupying the space between the young lens and the retina. The primitive vitreous early becomes vascular by the multiplication and extension of the branches of the hyaloid artery, which is continued from the central retinal vessels as far forward as the inner and posterior surface of the lens, where they spread out to aid in forming the vascular tunica lentis.

The vitreous body, therefore, must be regarded as composed of modified mesoderm, and presents the characteristics of embryonal connective tissue throughout the earlier periods of its growth. Later, the blood-vessels of the vitreous disappear and the structural elements become reduced to atrophic cells of irregular form and distribution: the remains of the hyaloid vessels are sometimes observed even after birth as a delicate cord stretching from the optic-nerve entrance toward the lens. (See page 403.)

The peripheral zone of the young vitreous becomes condensed, and produces the hyaloid membrane which limits the vitreous on all sides except behind the lens, and is continued forward to fade away over the ciliary region.

Development of the Eyelids.—This begins quite early as an upper and lower fold of the integumentary layer, which grow over the corneal surface until they meet and fuse. The fusion of the palpebral folds in man takes place early in the third month of fetal life, the union continuing until shortly before birth, when the permanent separation is effected by cleavage through the common epithelial layer formed by the union of the ectoderm along the line of juncture.

During the period of fusion the mesoderm contained within the palpebral folds, bounded externally and internally by coverings of ectoderm, differentiates into thin layers, which give rise to the subcutaneous tissues, the muscular structures, and the subconjunctival or tarsal stratum. The Meibomian and other glands contained within the lid are derived as ingrowths and proliferations of the ectoderm covering the adjacent surface of the immature lid. The tear-gland appears during the third month as a solid ingrowth of the conjunctival ectoderm close to the upper lid; later the epithelial ramifications acquire a lumen. The ocular muscles, together with the various structures contained within the orbit, with the exception of the nerve-fibers, primarily are derivatives of the mesoderm.

The foregoing sketch of the development of the eyeball shows that the derivatives of the outer and middle blastodermic layers may be grouped as follows:

A. From the ectoderm are derived—

Anterior epithelium of the cornea and its conjunctival continuation.

Crystalline lens, including the epithelium of its anterior capsule.

Retina, including the anterior extensions forming the *pars ciliaris* and *pars iridica*.

Sustentacular tissue of the optic nerve.

B. From the mesoderm are derived—

Corneal stroma and endothelium.

Sclerotic coat.

Vascular tunic, including the choroid and the connective-tissue stroma of the ciliary region and iris.

Vitreous body.

Suspensory apparatus of the lens.

Connective-tissue investments of the optic nerve.

Vascular tissues of the retina.

The epithelial tissues of the eyelids and conjunctival sac, including the lid-glands, the lachrymal gland, and the lining of the tear-channels, are derivatives of the ectoderm; the surrounding connective tissues are products of the mesoderm.

ANATOMY OF THE EYE.

The Orbits.—The orbits are horizontally-placed pyramidal fossæ, the anteriorly and somewhat outwardly directed bases of which correspond with the facial plane, their apices being occupied by the inner extremity of the sphenoidal fissure. The angles between the four conventional walls of the space are not sharply marked, but rounded off, so that the surfaces pass gradually one into the other, each orbital cavity approaching often more closely the conical than the pyramidal form. The inner walls, composed of the nasal process of the superior maxilla, the lachrymal, the ethmoid, and the body of the sphenoid, lie generally parallel with each other; the external walls, formed by the orbital surface of the malar bone and great wing of the sphenoid, on the contrary, form almost a right angle between their planes. The roof and floor, composed respectively of the frontal and small wing of the sphenoid and of the malar, the superior maxillary, and the palate bones, gradually converge toward the apex of the generally conical cavity.

The *orbital axes* do not correspond accurately with the horizontal plane, since at their posterior poles they lie from 15° to 20° above; when prolonged backward, the axes meet in the vicinity of the sella Turcica and include an angle of about 43°. The distance between the anterior ends of the orbital

axes is approximately 60 mm. The depth of the orbit varies from 40–45 mm., being usually from 3–5 mm. greater in the male than in the female skull. The capacity of the adult orbit approximates 30 c.cm.

The irregularly quadrilateral base of the orbit, corresponding to the facial apertures, is bounded by the thickened, rounded, and partially overhanging margins contributed by the frontal, malar, and superior maxillary bones. The apex is occupied by the inner and wider extremity of the sphenoidal fissure, the narrower continuation of which extends upward and outward as a conspicuous cleft separating the roof and outer wall of the orbit throughout the posterior half of their line of meeting. The optic foramen lies slightly to the inner and upper side of the apex of the orbit, within the smaller ala of the sphenoid. The angle between the external wall and the floor is occupied throughout its posterior three-fourths by the narrow and elongated sphenomaxillary fissure, which communicates with the sphenomaxillary fossa at its posterior inner end, and with the zygomatic fossa at its anterior outer extremity. The posterior part of the orbital floor is grooved by the beginning of the infraorbital canal; the contour of the anterior margin of the roof is interrupted by the supraorbital notch or foramen; the inner wall below lodges the lachrymal groove, formed by the lachrymal and superior maxillary bones, while higher, in close relation with the internal boundary of the arched roof, is the depression occupied by the pulley of the superior oblique muscle. Behind the external angular process lies the lachrymal fossa for the accommodation of the tear-gland.

The Eyelids and the Conjunctiva.—The eyelids are two broad movable folds of integument supplemented and strengthened by muscular bundles and dense fibrous tissue, and lined by a mucous membrane: they are attached to the upper and lower orbital margins, and aid in covering in the structures at the base of the orbit and the projecting anterior segment of the eyeball.

As already noted, the eyelids develop as duplications of integument which gradually approach, and, finally, about the end of the third month, fuse along the approximated edges to form a closed sac surrounding the anterior segment of the eyeball. Before birth the permanent separa-

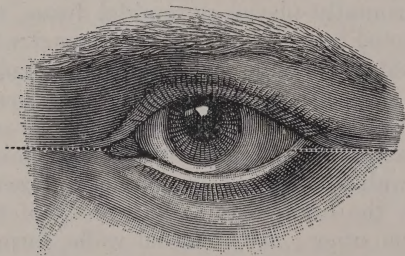


FIG. 12.—Eyelids naturally opened, from a photograph (Merkel). Horizontal plane passes through inner canthus.

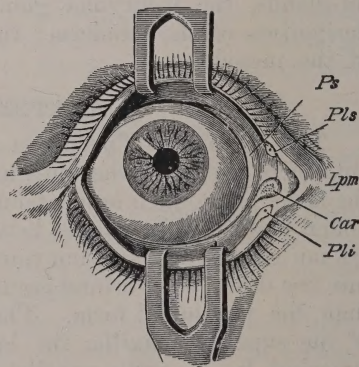


FIG. 13.—Right eye from before, the eyelids separated by hooks (Quain-Merkel): *Ps*, plica semilunaris; *Pls*, *Pli*, superior and inferior lachrymal puncta; *Car*, lachrymal caruncle; *Lpm*, internal tarsal ligament.

tion of the lids takes place, by which time the skin in relation to the eyeball has lost its original integumentary characteristics, and has assumed those of a mucous membrane—the conjunctiva.

The palpebral fissure, bounded by the arched free margins of the eyelids, resembles an almond in its general form (Fig. 12). Its length, measured

from its extreme angles, is usually between 28 and 30 mm., and its greatest width when open is about 13 mm.

Individual variations from these measurements are very common, shortening and narrowing of the opening being not infrequent to the extent of several millimeters; slight differences in the palpebral clefts of the two eyes exist in many instances.

The symmetry of the palpebral opening is broken by the variation in its two angles, the *outer* or *lateral canthus* being bounded by the converging borders which directly continue the arches of the lids until they meet at an acute angle, while the *inner* or *mesial canthus* is situated at the junction of the slightly arching and almost parallel margins which enclose the diverticulum known as the *lacus lacrymalis*, or *tear-lake*. The latter is formed by the sharp deviation which the free lid-margins undergo about 5 mm. before reaching their mesial juncture, their subsequent direction being almost horizontal until they converge just before uniting (Fig. 12).

The space included between the rounded mesial extremities of the eyelids, or lachrymal lake, is partly occupied by a low, spongy-looking elevation of

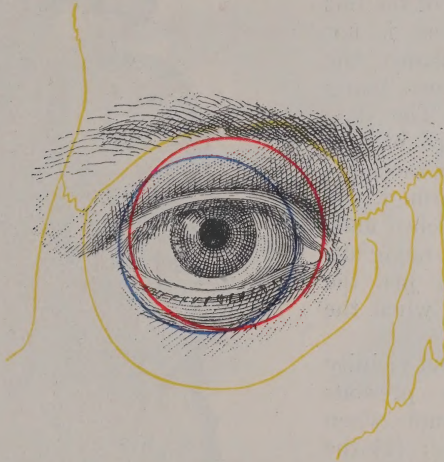


FIG. 14.—Relations of the palpebral opening to the eyeball (blue), conjunctival sac (red), and orbit (yellow) (Merkel).

reddish color, the *caruncula lacrymalis*; the caruncle is an isolated area of skin containing a few large modified sweat-glands, in addition to sebaceous follicles connected with the follicles of the minute hairs which spring from the summit of the elevation. Fat-cells and involuntary muscular tissue are also usually present. The lateral or outer extremity of the lachrymal caruncle sinks into the surrounding conjunctival tissue, which in this position presents a vertically placed crescentic fold, the *plica semilunaris* (Fig. 13). This duplicature represents a rudimentary nictitating membrane, or third eyelid, which in many lower types, as birds or amphibians, attains conspicuous dimensions. Minute cartilaginous plates and a few glandular acini lodged within the base of the semilunar fold are additional rudimentary representatives of the crescentic cartilage and Harder's gland of the lower animals.

The relation of the anterior segment of the eyeball to the palpebral opening varies with the position of the eyeball and the approximation of the lids. When the eyelids are apart and the eye directed horizontally forward toward distant objects, the cornea lies midway between the lateral canthus and the

lachrymal puncta, or slightly external to the middle of the line joining the canthi. The axis of the palpebral cleft does not quite coincide with the horizontal, since the mesial canthus lies a little lower than the external. The cornea is unequally covered by the two lids, the lower lid usually not quite reaching the corneal margin, while the upper lid covers a small variable segment of the periphery above. The extent to which the cornea is covered by the upper lid is an important factor in producing staring or somnolent expressions (Fig. 14).

Closure of the eye is chiefly effected by the upper lid, which from its larger size and general mobility covers about three-fourths of the exposed portion of the eyeball. The excursion made by the upper lid in closing and opening the palpebral orifice measures about 3 mm., the distance traversed by the lower lid being somewhat less. When the eyelids are closed during sleep the eyeball is rotated, so that the cornea lies above and slightly to the median side: closure of the lids while awake, however, is not attended with such change, the position of the cornea being then maintained. The slit-like palpebral fissure of the closed lids lies below the horizontal line drawn through the mesial canthus, the arched margin of the upper lid being directed downward, or just the opposite to its form when the eye is open.

The eyelid in the vicinity of its free border presents three principal strata when examined in section: (1) the skin and subcutaneous tissue; (2) the muscular layer; (3) and the tarsal plate covered with the conjunctiva (Fig. 15).

The *integument* of the eyelid presents the usual details of delicate skin in other locations, the hair-follicles and surface hairs being, however, extremely small and the subcutaneous tissue devoid of fat. The rounded outer margins of the lids bear conspicuous large hairs, the eyelashes or *cilia*; those of the upper lid are larger and more numerous than those of the lower, the former measuring from 9–12 mm. in length and numbering about 150, while the latter are only half as many and only from 6–8 mm. long. The hair-follicles of the cilia

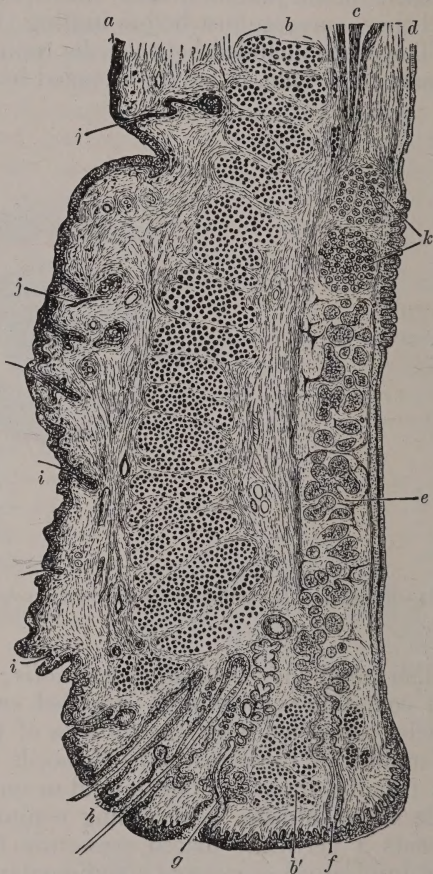


FIG. 15.—Vertical section through the upper eyelid (Waldeyer): *a*, skin; *b*, cut fibers of the orbicularis; *b'*, ciliary bundle of orbicularis; *c*, muscle (involuntary) of Müller; *d*, conjunctiva; *e*, tarsal plate in which are imbedded the Meibomian glands (*f*); *g*, sebaceous glands near cilia (*h*); *i*, small hairs of integument; *j*, sweat-glands; *k*, posterior tarsal glands.

are arranged in double or triple rows near the anterior border of the lid. The average life of an eyelash is probably about four months, the older and thicker cilia being constantly replaced by the young and slender hairs.

The muscular layer of the eyelid consists essentially of the palpebral portion of the *orbicularis palpebrarum*, which is arranged as concentric fibers, which occupy the interval between the subcutaneous tissue and the tarsal plate and its associated tendons. The elliptical muscular bundles, when cut in longitudinal section of the eyelid, appear as irregular groups of transversely cut fibers. The innermost of the concentric bundles of the *orbicularis* lies close to the inner margin of the lid, and constitutes a robust and partly isolated group of fibers known as the ciliary muscle or muscle of Riolan. The fibers composing these bundles surround the structures occupying this part of the border of the lid, including the hair-follicles, sebaceous glands, glands of Moll, and the ducts of the Meibomian glands (Fig. 15).

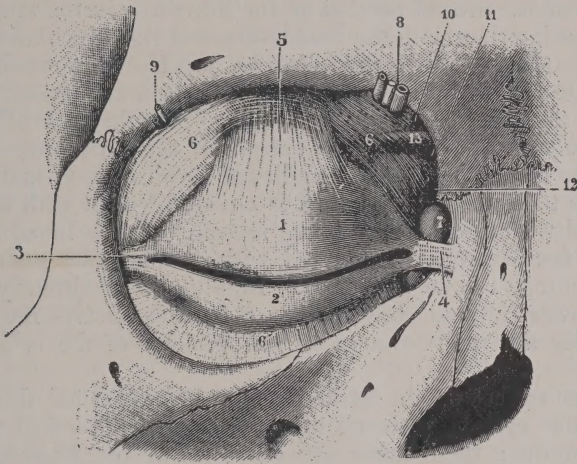


FIG. 16.—Dissection of the tarsal plates and their ligaments (Testut): 1, 2, upper and lower tarsus; 3, 4, external and internal tarsal ligaments; 5, expanded tendon of levator palpebrae; 6, 6', septum orbitale; 7, lachrymal sac; 8, supraorbital vessels and nerve; 9, lachrymal artery and nerve; 10, 11, openings for supra- and infratrochlear nerves; 12, opening for the angular vein; 13, tendon of superior oblique muscle.

The fibrous stratum of the eyelid has as its principal constituent the crescentic plate of firm fibrous tissue known as the *tarsus* or *tarsal cartilage*. This structure, composed entirely of dense connective tissue and without cartilage-cells, exists in both eyelids as a sustaining band, which is important in maintaining the proper form of the lid-margins. The tarsal plates vary in size in the two eyelids, the upper tarsus being broader and more arched than that within the lower lid. The extremities of the tarsi are united to each other and to the orbital walls by firm bands of fibrous tissue, the *mesial* and *lateral palpebral ligaments*. The upper tarsus, corresponding with the greater width of the superior lid, is wider than the lower plate, measuring about 10 mm. at the point of its greatest breadth, or about twice the width of the lower. In length the tarsi are almost equal, and extend along nearly the entire lid-margin, about the middle of which they possess their greatest thickness, diminishing toward either end as well as toward their convex borders.

The tendon of the levator palpebrae, as its lower broadened end expands

into the upper eyelid, becomes closely related to the inward extension of the orbital fascia, which, as the *septum orbitale*, passes from its peripheral attachment at the orbital margin into the eyelids, forming a partition which closes in the periocular structures and prevents the extrusion of the orbital fat between the eyeball and orbit (Fig. 16).

In the upper lid the *septum orbitale* or palpebral fascia blends with the tendon of the levator palpebræ, the two forming a layer of connective tissue which intervenes between the orbicularis and the conjunctiva above, and is largely inserted into the tarsus below, some bundles passing in front of the tarsal plate. In the lower lid the septum joins the tarsus in common with fascial expansion connected with the inferior straight and oblique muscles.

The relations of the upper tarsal plate to the expanded tendon of the levator palpebræ muscle are most intimate. The fibrous tissue of the tendon of this muscle is arranged in three layers—the upper, which expands into bundles which are inserted into the summit of the conjunctival fornix and adjacent part of the orbital portion of the lid, while in the tarsal portion the fibrous bundles interlace with the muscle-fibers of the orbicularis palpebrarum, on the inner surface of which they form an imperfect fibrous sheet.

The middle part of the levator aponeurosis contains bundles of involuntary muscle, the so-called *superior palpebral* muscle of Müller, which are inserted principally into the upper margin of the tarsal plate. The lower stratum of the tendon consists of bundles of fibrous tissue, and is attached at various points to the conjunctiva, and is closely blended with the fascial process connected with the superior rectus muscle. In the lower lid the expansions of the fascial process connected with the inferior rectus replace the levator aponeurosis of the upper lid. Bundles of involuntary muscle occur also in the lower lid, and constitute the *inferior palpebral* muscle, while the fibrous bundles are interwoven with the fasciculi of the orbicularis palpebrarum.

The ocular surface of the tarsal plates, when inspected during life after eversion of the eyelids, presents numerous parallel vertical rows of small yellowish granules: these latter are the acini of the *Meibomian* or *tarsal glands* seen through the conjunctiva. When examined more carefully the tarsal glands are seen to be enlarged and modified sebaceous glands imbedded within, and occupying almost the entire thickness of, the dense connective tissue forming the tarsi; they number between thirty and forty in the upper lid and from twenty to thirty in the lower. Each gland consists of a straight or slightly sinuous vertical duct, from the sides of which open numerous diverticula or alveoli. The Meibomian glands occupying the middle of the tarsi are longer and more vertically disposed than those placed nearer the extremities of the plates, where the glands, in addition to being shorter, not infrequently terminate by sharply bending on themselves. The ducts terminate as minute puncta arranged in a row along the margin of the eyelid near its sharp inner border, and are lined by a direct continuation of the stratified squamous epithelium of the adjacent integument; the acini of the glands are clothed with cuboidal cells which resemble the elements found in other sebaceous glands, containing numerous fat-droplets within their protoplasm.

The free margins of the eyelids present an outer and inner border, which differ in their forms and relations; the outer border is somewhat rounded and beset with the long curved cilia, while the inner is sharply defined by the line of juncture of integument and conjunctiva, along which open the orifices of the Meibomian glands. In addition to the hair-follicles and associated

sebaceous glands lodged within the palpebral margin, a number of enlarged and modified sweat-glands, or *glands of Moll*, lie about midway between the two borders of the lid, and open in close proximity to or into the mouths of the hair-follicles; the glands of Moll in the upper lid extend into the surrounding tissue to a depth equal to the extremities of the hair-follicles in the lower lid—indeed, exceeding the hair-follicles in length. The ends of the hair-follicles, sebaceous glands, and glands of Moll are surrounded by the deepest fibers of the ciliary muscle of Riolan, the greater part of the group of muscular bundles lying between the glands of Moll and the tarsus.

The conjunctiva invests the ocular surface of the eyelids and the anterior segment of the eyeball, and is, therefore, appropriately divided into the *palpebral* and *bulbar* portions. The annular fold which marks the peripheral limit of the conjunctival sac is known as the *fornix conjunctivæ*.

The palpebral conjunctiva presents a further subdivision into the *tarsal* and *orbital* areas, based on the differences which characterize these two segments. The conjunctiva covering the tarsus, directly continuous with the integument at the lid-margin, so closely adheres to the firm fibrous tarsal plate that the conjunctival membrane is immovably attached to the fibrous lamella; the Meibomian glands indistinctly show through the conjunctiva as vertically arranged, parallel, yellowish-white lines.

The *orbital conjunctiva*, covering the fascial and tendinous expansions which are blended with the arched border of the tarsi, is attached by the loose subconjunctival connective tissue to the subjacent structures, upon which it freely moves. In contrast to the velvety appearance of the tarsal portion, the orbital conjunctiva is smooth and glistening, although less firmly fixed to the underlying tissues.

The peculiar velvety appearance of the tarsal conjunctiva depends upon the presence of minute interlacing furrows and intervening ridges and papillæ; the latter are especially well developed near the orbital border of the tarsus. The lymphoid characteristics of the subepithelial layer of the tarsal conjunctiva are conspicuous in the situations in which the tarsal papillæ are best developed; hence in the vicinity of the tarsal border the general lymphoidal infiltration is often replaced by local aggregations of cells in the form of lymph-follicles or trachoma-glands. These structures, however, are very variable in their position, number, and size, and may be entirely wanting or found in other parts of the conjunctival sac.

At the mesial canthus the conjunctiva lines the lachrymal lake, and on the caruncle maintains its primary integumentary character. Just external or lateral to the puncta the conjunctiva presents a well-marked vertical crescentic fold, the *plica semilunaris*, which represents a rudimentary nictitating membrane.

The conjunctiva covering the tarsi and the cornea is more fixed than elsewhere, being in these situations so inseparably attached to the subjacent structures that it follows the frequent movements of these parts.

The remaining portions of the conjunctiva are separated from the underlying structures by the subconjunctival tissue, which, on account of its loose and elastic nature, allows the conjunctiva to be moved to and fro with readiness. The same loose character of this areolar tissue permits the accumulation, and consequent distortion, of extravasated fluids to an enormous degree.

The epithelium lining the several portions of the conjunctival sac varies; thus, over the tarsal region the cells retain the stratified squamous character of the adjacent palpebral integument; shortly beyond the attached border of the tarsi the cells assume a columnar form, which they retain over the

fornix on to the bulbar surface, where the cells again become squamous. This latter type includes the elements constituting the anterior epithelium of the cornea. The subepithelial stroma throughout the orbital conjunctiva is especially rich in elastic fibers, which are well represented in the fornix and bulbar conjunctiva almost as far as the corneal margin. In the latter vicinity the tunica propria of the conjunctiva ends by blending with the sclerotic, while the epithelium alone continues uninterrupted over the corneal surface: the termination of the conjunctival stroma is sometimes indicated by an annular thickening which corresponds to the limbus corneae in position.

Glands have been described within the more concealed portions of the conjunctival sac, those of the fornix very closely resembling the tear-gland in structure. Adipose tissue not infrequently occurs as groups of fat-cells; in advanced age the accumulation becomes conspicuous as a yellowish patch close to the corneal margin.

The blood-vessels of the eyelids are derived from several sources (Fig. 17),

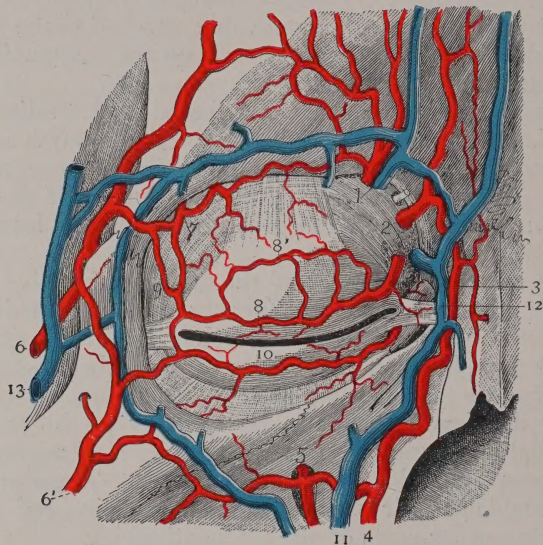


FIG. 17.—Blood-vessels of the eyelids (Testut): 1, supraorbital artery and vein; 2, nasal artery, anastomosing with terminal branch (3) of facial artery (4); 5, infraorbital artery; 6, superficial temporal artery; 6', malar branches of transverse facial; 7, lachrymal; 8, superior palpebral artery, with secondary arch (8'), and anastomoses (9) with temporal and lachrymal; 10, inferior palpebral artery; 11, facial vein; 12, angular vein; 13, superficial temporal vein.

since all the surrounding neighboring arteries contribute branches which more or less directly take part in the supply of the palpebral folds. The principal blood-supply of the eyelids is from the internal and external palpebral arteries; the former are direct branches from the ophthalmic, usually by a common trunk given off just before the ophthalmic artery divides into its frontal and nasal branches, and the latter are derived from the lachrymal. The internal palpebral arteries, commonly somewhat larger than the external, include a superior and inferior, which after piercing the palpebral fascia as the marginal arteries, run along the free margin of the corresponding eyelid, from 2.5–3 mm. removed, and anastomose with the external palpebral vessels to form the upper and lower tarsal arches. The transverse facial and superficial temporal contribute branches which join in the anastomotic circuit at the outer margin of the orbit.

In the upper eyelid, and sometimes less perfectly developed in the lower as well, a secondary tarsal arch is formed by a branch of the superior palpebral, the superior marginal artery, which runs along the convex border of the tarsal plate between the lamellæ of the tendon of the levator palpebræ. Numerous small twigs join the tarsal arches, and establish an elaborate anastomosis in which the infraorbital and facial arteries also take part. Branches of distribution pass forward from the tarsal arches for the supply of the integument and orbicularis, and backward, by means of perforating and encircling twigs, to supply the tarsus and Meibomian glands and the palpebral conjunctiva. The supply of the tarsus is maintained especially by the superior tarsal arch, while the inferior arch is devoted to the nutrition of the margin of the eyelid. Just before the internal palpebral artery reaches the lid numerous twigs are distributed to the lachrymal caruncle, tear-sac, and the tissues surrounding the latter and the canaliculi. The nasolachrymal canal receives its supply from a branch formed by the anastomosis of the infraorbital with the inferior internal palpebral artery.

The *veins of the eyelids* do not accurately follow the course of the arteries, but are arranged in two series, the post-tarsal and pre-tarsal. The former collects the blood from the conjunctival surface and a part of the Meibomian glands, and is tributary to the ophthalmic vein; the latter receives radicles from the integument, muscular structure, and the Meibomian glands, and forms a subcutaneous network which passes into the superficial temporal and facial veins.

The *lymphatics of the eyelids* are disposed as a pre-tarsal and a post-tarsal network, the former of which receives the tissue-juices from the integument and muscle, the latter from the conjunctiva and Meibomian glands. Perforating branches establish communication between the two networks. The submaxillary and parotid lymph-glands receive the larger lymph-vessels from the palpebral networks.

The *sensory nerves of the eyelids* are derived from the ophthalmic and superior maxillary divisions of the trifacial. The upper eyelid is supplied principally by branches from the frontal and supraorbital nerves, which freely join and form a *superior marginal plexus* along the edge of the eyelid. The chief supply of the lower lid is derived from the branches of the infraorbital nerve, which ascend to the border of the lower lid, where they form the *inferior marginal plexus*. These nerves are supplemented by twigs from the supra- and infratrochlear branches, which are distributed to the area around the mesial canthus. An especial lower branch from the infratrochlear nerve supplies the mucous membrane of the lachrymal sac. The terminal branches of the lachrymal nerve become subcutaneous a short distance beyond and above the external canthus, contributing a few twigs to the eyelids, but ending chiefly in the integument to the outer side of the orbit.

The *motor nerves* distributed to the muscular structures of the eyelids include branches from the oculo-motor to the levator palpebræ, and from the facial to the orbicularis palpebrarum; additional sympathetic fibers are distributed to the involuntary muscle of the lids. The ramifications of the motor and sensory nerves freely intermingle, and constitute a network of considerable complexity within the superficial structures of the eyelids.

The Contents of the Orbit.—The orbital contents, including the visual apparatus, consisting of the eyeball and its associated nerves, muscles, and glands, and the incidental structures, as branches of the ophthalmic blood-vessels and the trifacial nerve, which pass through the orbit *en route* to more remote parts, are supported by the general fibro-adipose intraorbital tissue.

This periocular cushion of fat occupies the interspaces between the various connective-tissue partitions and bands constituting the fibrous framework, which separates, as well as holds together, the various constituents of the orbital contents. Variations in the amount of the intraorbital fat affect the relations of the eyeball to the orbital opening, a conspicuous example of such change being familiar in the sunken or "hollow-eyed" appearance following illness or conditions favorable to the absorption of adipose tissue.

Since the majority of the structures within the orbit are grouped around the eyeball as parts subservient and accessory to the visual organ, the position of the ocular bulb with relation to the orbit is of importance, inasmuch as this

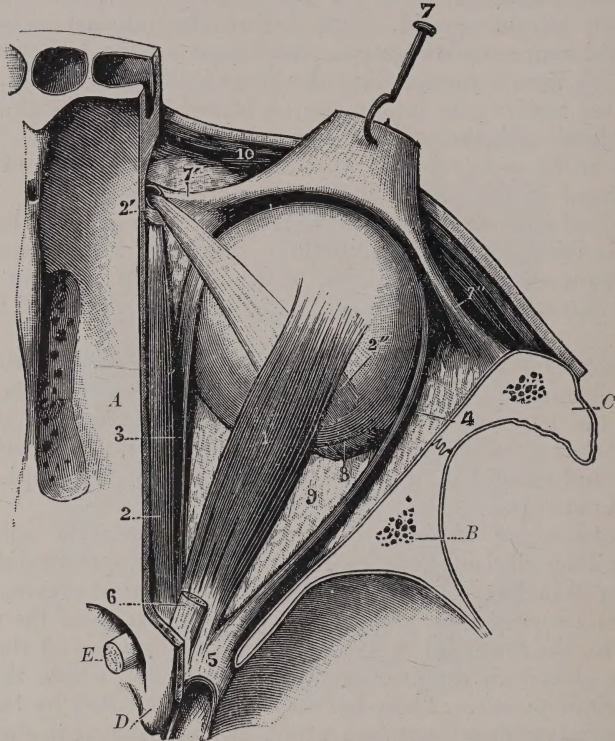


FIG. 18.—Ocular muscles of right side, viewed from above, after removal of roof of orbit (Testut): A, frontal bone; B, section of great wing of sphenoid; C, section of malar bone; D, anterior clinoid process; E, optic nerve; 1, superior rectus; 2, superior oblique muscle with its pulley (2') and its insertion into the eyeball (2''); 3, internal rectus; 4, external rectus; 5, common origin (ligament of Zinn) of muscles; 6, cut tendon of levator palpebrae; 7, 7', 7'', palpebral expansion of same; 8, insertion of inferior oblique; 9, intraorbital cushion of fat; 10, orbicularis palpebrarum.

primary relation largely determines the secondary arrangement of the associated structures. The eyeball corresponds with the orbit neither in the direction of its axis nor in the position of its center, since the bulbar axis subtends with that of the orbit an angle of from 42° to 45° , while the eyeball itself lies 1 or 2 mm. nearer the lateral than the mesial wall, and probably also slightly nearer the roof than the floor. Owing to the eccentric position of the eyeball, together with the receding plane and the slight projection of the lower and outer segment of the orbital margin, the position most favorable to reach the bulb is the vicinity of the inferior and external angle. The ball occupies the anterior half of the orbit, its position being such that a line joining the upper and lower margins of the orbit opposite the anterior pole comes in contact with the anterior corneal surface.

The Ocular Muscles.—The eyeball is rotated around its three principal axes by the individual or combined action of six muscles—the four straight and the two oblique; an additional seventh muscle, the *levator palpebræ*, is attached to the upper eyelid, which it raises.

Of the six muscles inserted into the eyeball, all except the inferior oblique, which occupies the anterior part of the orbit, take their origin from the apex of the orbit and pass forward to their insertion. The elevator of the eyelid has a similar course, since its origin is closely associated with the straight muscles of the ball (Fig. 18).

The four straight or recti muscles may be considered as having a common tendinous origin from the fibrous ring which is attached to the apex of the orbit. This fibrous oval ring, the *ligament of Zinn*, passes down the inner side of the optic foramen as far as its lower margin, then extends transversely across the inner part of the sphenoidal fissure, to the lower border of which it is attached, again bridges the sphenoidal fissure about the middle, and finally gains the upper margin of the optic foramen. The tendinous origins of the straight muscles from the ligament lie so closely placed that at first they are continuous, and form a somewhat flattened tube which extends between 2 and 3 mm. before separating into the individual tendons of the recti muscles. The tendinous tube is particularly strong above and below, the thickened bands developed within the ring at these points being sometimes described as the *common tendons*. The origins of the levator palpebræ and superior oblique form a second imperfect concentric layer to the inner side of the optic foramen, where they constitute a crescentic zone in close relation to the origin of the superior and internal rectus.

The *superior rectus* arises from the upper border of the optic foramen and beneath the levator palpebræ; the *internal rectus* occupies the mesial or inner and part of the lower margin of the foramen; the *inferior rectus* springs from its lower border; while the *external rectus* possesses two heads. The lower and larger head is attached to the inferior and inner border of the sphenoidal fissure and that part of the tendinous ring which stretches across the fissure; the upper and outer, or accessory, head springs from the outer wall of the sphenoidal fissure, being separated from the main part of the muscle by a narrow interval occupied by a small amount of connective tissue and the third and sixth nerves and the nasal branch of the fifth, together with the ophthalmic veins. The four recti muscles proceed forward toward the eyeball, the posterior half of which they embrace above, below, and at the sides, and are inserted into the sclera by short, thin, and slightly broadened tendons a short distance behind the corneal margin (Fig. 19).

The straight muscles differ considerably, when compared with one another, in their general development, length, breadth, and exact place of insertion. As is to be expected from its unusual work in converging the eyes, the internal rectus leads in its general development, being the broadest and strongest, as well as possessing the longest tendon and most anteriorly situated place of insertion. The superior rectus is the smallest and weakest of the straight muscles, and has its insertion farthest from the cornea, but possesses the broadest line of attachment; the inferior and external recti exceed the others in their length.

Shortly before reaching the eyeball the muscular fibers of the recti terminate in thin membranous and somewhat expanded tendons of insertion, the fibers of which not only blend, but become intimately interwoven, with the tissue of the sclerotic coat. The lines of attachment, the slight convexities of which are directed toward the cornea, vary in their relation to the corneal

margin, that of the internal rectus being nearest, and that of the superior rectus farthest removed. The length of the tendons of insertion of the

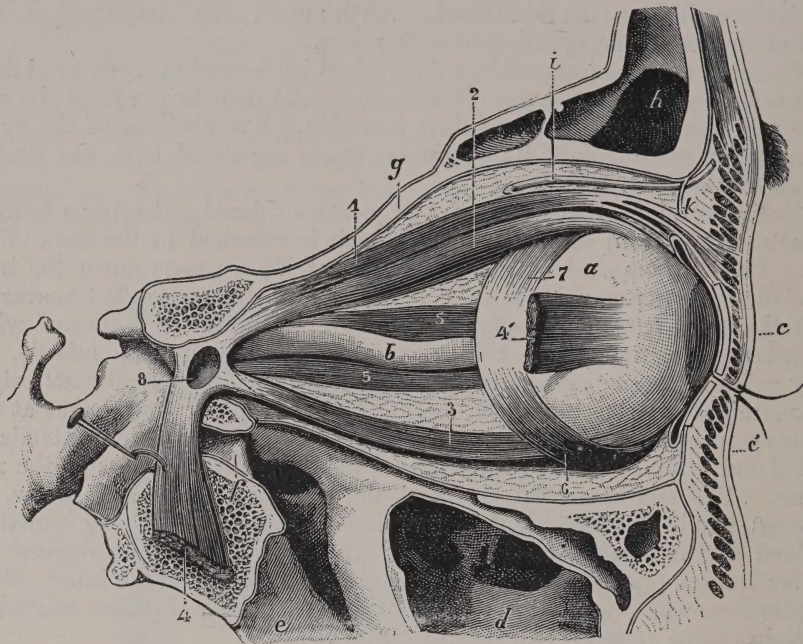


FIG. 19.—Ocular muscles viewed after removal of lateral wall of orbit (Testut): *a*, eyeball; *b*, optic nerve; *c, c'*, eyelids; *d*, maxillary sinus; *e*, pterygoid plate; *f*, foramen rotundum; *g*, roof of orbit; *h*, frontal sinus; *i*, supraorbital nerve; *k*, septum orbitale; *l*, levator palpebrae superioris; 2, 3, superior and inferior recti; 4, 4', portions of the cut external rectus; 5, internal rectus; 6, inferior oblique; 7, insertion of superior oblique; 8, annular ligament or tendon of Zinn.

recti and the distance from the cornea, determined by the accurate measurements of Merkel and of Fuchs, are as follows:

	Length of tendon.	Distance of insertion from cornea.
Internal rectus	8.8 mm.	5.5 mm.
Inferior rectus	5.5 "	6.5 "
External rectus	3.7 "	6.9 "
Superior rectus	5.8 "	7.7 "

The insertion-lines, therefore, progressively recede from the corneal margin from the insertion of the internal rectus to that of the superior, with a cor-

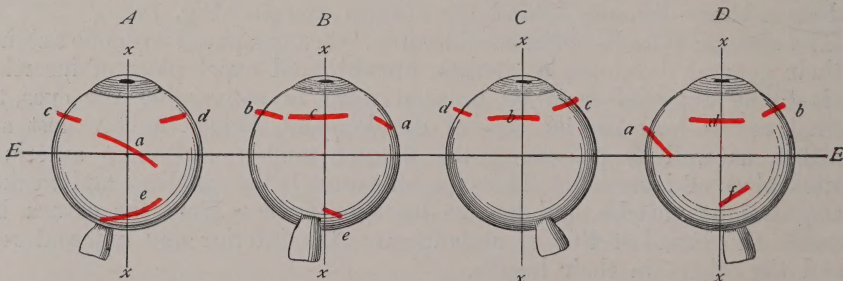


FIG. 20.—Diagram of the positions of the insertions of the ocular muscles (Fuchs-Testut). Right eye: *A*, viewed from above; *B*, from nasal side; *C*, from below; *D*, from temporal side; *x, x*, antero-posterior axis; *E, E*, equator; *a, b, c, d*, superior, inferior, internal, and external rectus; *e, f*, superior and inferior oblique.

responding diminution in the effectiveness of the pull of the several muscles. As suggested by Tillaux, the distance of the insertions from the

cornea may be taken, for practical purposes, respectively as 5, 6, 7, and 8 mm. (Fig. 20).

The *superior oblique*, or *trochlearis*, arises about 2 mm. in front of the inner margin of the optic foramen; it proceeds forward and upward in close relation to the orbital wall, as far as the trochlear fossa, where its rounded tendon traverses the short fibrous tube of the trochlea, and, at the anterior extremity of the canal, changes its direction at an angle of about 50° , the muscle passing backward and outward between the eyeball and the anterior end of the superior rectus, to find its insertion into the sclerotic beneath the latter muscle, about midway between the corneal margin and the optic nerve.

The *inferior oblique*, situated within the anterior part of the orbit, arises from the mesial wall of the orbit, close to its anterior margin, from a slight depression in the orbital plate of the maxilla over the outer wall of the naso-lachrymal duct. Starting in short tendinous fibers, the muscle leaves the orbital wall and sweeps in a gentle curve outward, backward, and upward, passing between the inferior rectus and the floor of the orbit, and terminates in a tendon which is inserted into the sclerotic at the posterior and outer part beneath the rectus externus (Fig. 21).

The *levator palpebræ superioris*, as indicated by its name, is related to the upper eyelid, and claims attention in this place only on account of its incidental association with the ocular muscles. In its origin it is closely related to the superior rectus, arising by a pointed tendon above and in front of the optic foramen. The muscle broadens in its course along the roof of the orbit, close to the periosteum for the greater part of its length, and covers the posterior half of the superior rectus; on reaching the anterior part of the orbital cavity, a little behind its superior margin, it descends through the adipose tissue as a membranous expansion which is attached to the root of the upper eyelid. Its insertion is peculiar, and consists of two distinct layers: the upper anterior of these is fibrous and passes in front of the tarsal plate, blending with the fibers of the orbicularis, while the lower posterior layer contains non-striped muscular tissue, and is inserted into the upper border of the tarsus, constituting what is often described as the *superior palpebral muscle of Müller* (Fig. 23).

Closely associated with the actions of the superior and inferior recti are the oblique muscles, by means of which the obliquity of the pull of these straight muscles is neutralized. The action of the *superior oblique*, from the location of the insertion and direction of its fibers, when the eyeball is in the primary position, is to move the cornea downward and outward; that of the inferior oblique is to cause the cornea to move upward and outward. The slight outward rotation thus effected takes place, however, in opposite directions, since when caused by the superior oblique the movement of the cornea

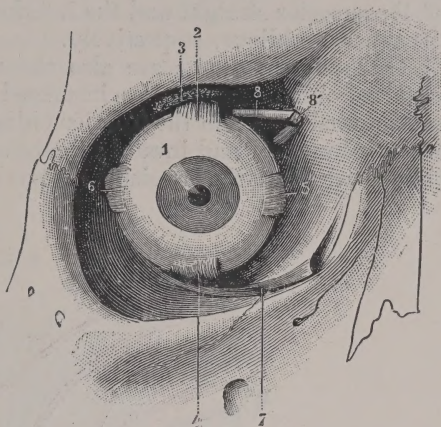


FIG. 21.—The eyeball *in situ* with its muscles after removal of surrounding parts of orbital contents (Testut): 1, eyeball; 2, superior rectus; 3, levator palpebræ; 4, inferior rectus; 5, internal rectus; 6, external rectus; 7, inferior oblique; 8, superior oblique; 8', pulley and reflected tendon of same.

is from within outward, while when produced by the inferior oblique the upper half of the vertical diameter is displaced outward, the lower half at the same time being deflected inward. The obliquity of the pull of the oblique muscles is, therefore, well adapted to neutralize the obliquity attending the contraction of the superior and inferior recti, and, in point of fact, simple elevation and depression of the cornea are effected by the combined action of the superior straight and the inferior oblique and the inferior straight and the superior oblique, respectively.

Oblique movements are also the results of the associated efforts of the recti and oblique muscles, as instanced in the common action of the superior and internal recti and the inferior oblique in movements by which the cornea is carried upward and inward; the inferior and external recti and the superior oblique are similarly associated in moving the cornea downward and outward.

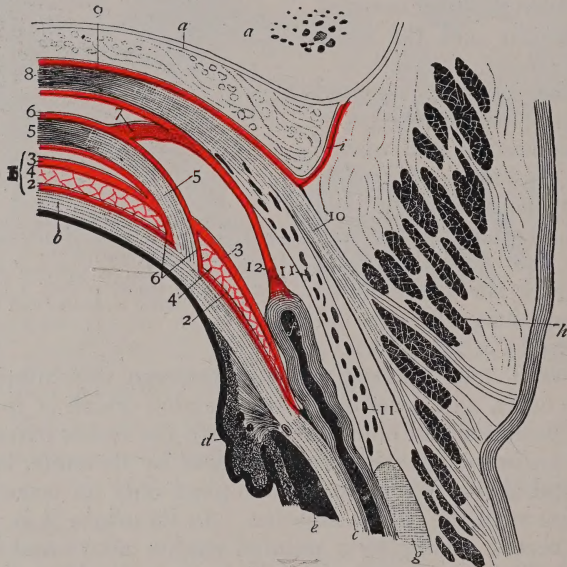


FIG. 22.—Semi-diagrammatic view of the relations of the orbital fascia with the superior muscles (Testut): *a*, frontal bone, with its periosteum (*a'*); *b*, sclerotic; *c*, cornea; *d*, ciliary process; *e*, anterior chamber; *f*, superior fornix of the conjunctiva; *g*, superior tarsus; *h*, orbicularis palpebrarum; *i*, septum orbitale; *j*, capsule of Tenon, consisting of its inner (2) and external (3) wall and the enclosed lymph-space (4); 5, 5', 6, respectively the belly, tendon, and sheath of the superior rectus; 7, orbital prolongation; 8, levator palpebrae, with its sheath (9) and its conjunctival (10) and muscular (11) insertions; 12, its prolongation and insertion into the fornix conjunctivæ.

In all other oblique movements of the cornea, likewise, the straight muscles are supplemented by the oblique, the desired motion representing the resultant of the forces exerted. Abduction and adduction further influence the action of the superior and inferior recti in consequence of the alterations in the direction of the pull; thus, when the eyeball is strongly abducted the transverse axis coincides with the axis around which elevation and depression occur, in which case the superior and inferior recti exert a simple action without their accustomed tendency toward oblique or rotary movement. (See also page 100.) The actions of ocular muscles are further described on pp. 497, 498.

The Orbital Fascia.—The periosteum of the orbit, directly continuous with the intracranial dura through the sphenoidal fissure, forms a funnel-shaped investment, which encloses the orbital contents and becomes blended with the external periosteum around the margins of the orbit. Numerous

septa of fibrous tissue are intimately connected with the inner surface of the periosteum on the one hand, and extend between the various structures lodged within the orbit, to which they afford support and protection on the other; the framework thus formed is largely occupied by the cushion of periorbital fat which fills the interspaces between the eyeball, blood-vessels, nerves, and muscles.

In the immediate vicinity of the eyeball the intraorbital fibrous tissue becomes condensed to form a fascial investment which surrounds the greater part of the organ; this fibrous envelope is known as the *tunica vaginalis oculi*, or *capsule of Tenon*. This consists of a tunic of fascia of considerable strength which surrounds the posterior two-thirds of the eyeball, from which it is separated by a narrow lymph-cleft, the *space of Tenon*; the interval between

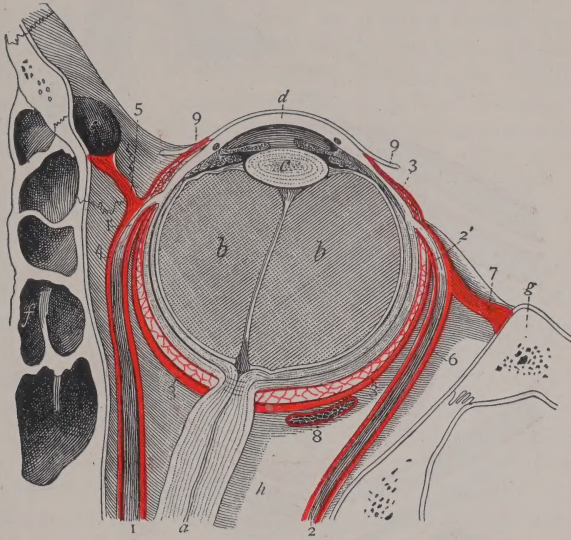


FIG. 23.—Semi-diagrammatic view of the orbital fascia of right side, seen after horizontal section of the eyeball and orbit, the lower half of the eyeball being represented (Testut): *a*, optic nerve; *b*, vitreous body; *c*, lens; *d*, cornea; *e*, section of lachrymal sac; *f*, ethmoid cells; *g*, malar bone; *h*, floor of orbit; 1, 2, internal and external rectus, with their tendons (1', 2'); 3, capsule of Tenon; 4, sheath of internal rectus with its orbital prolongation (5); 6, sheath of external rectus, with its orbital prolongation (7); 8, inferior oblique, with its sheath; 9, conjunctiva.

the eyeball and capsule is bridged by numerous delicate bundles of fibrous tissue which pass from the fibrous tunic to the adjacent sclera, thus subdividing the general cavity into a great number of imperfectly separated, freely intercommunicating spaces. The inner surface of the capsule, as well as the outer surface of the sclera and the trabecula, is clothed with endothelial plates, the entire space of Tenon strongly recalling the intracranial sub-arachnoidean lymph-space, which it closely resembles. The loose attachment of the capsule to the eyeball facilitates the free play of the visual organ in the fossa thus formed within the peribulbar adipose cushion, the eyeball moving in the capsule in a manner somewhat resembling an articulation.

The relations of Tenon's capsule are so complicated by its prolongations and attachments to surrounding structures that special reference to these is desirable. Posteriorly, the capsule extends as far as the point at which the optic nerve pierces the sclerotic coat, where it fuses with the sclera and outer sheath of the nerve as the latter blends with the fibrous tunic of the eyeball; likewise the ciliary arteries and nerves are excluded from the space. Ante-

riorly, the capsule lies beneath the ocular conjunctiva, with which it blends close to the margin of the cornea. If the conjunctiva is divided by a circular incision just posterior to the corneal margin, the capsule of Tenon will be found so closely united with the conjunctiva that reflection of the latter structure will open Tenon's space and expose the capsule at its anterior limit (Fig. 23).

The tendons of the various ocular muscles pierce the capsule of Tenon in order to gain their insertions into the sclera, which may thus be regarded as lying within the space of Tenon, although the tendons are separated from actual contact with the lymph-stream by means of an endothelial covering. The slit-like openings in the capsule made by the passage of the tendons are strengthened by local thickenings of the fibrous tunic, from which tubular

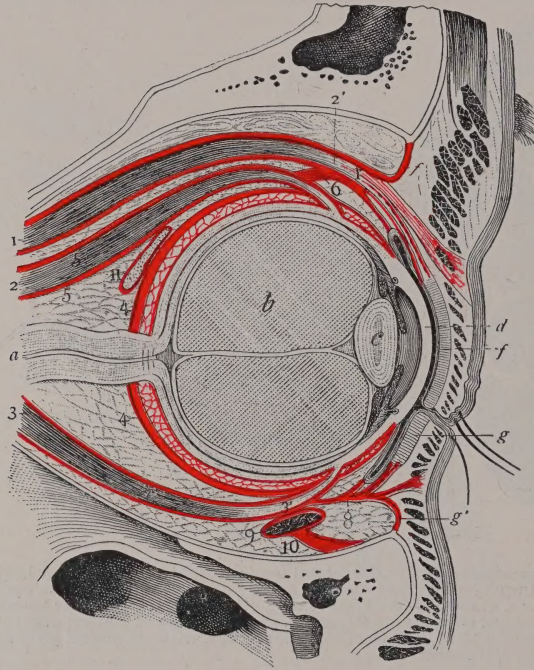


FIG. 24.—Semi-diagrammatic view of relations of orbital fasciæ as seen after sagittal section of the right eye: the internal half of orbit *in situ* (Testut): *a*, optic nerve; *b*, vitreous body; *c*, crystalline lens; *d*, cornea; *f*, *g*, upper and lower tarsal plates, with their ligaments (*f'*, *g'*); 1, levator palpebrae, with its tendon; 2, 3, superior and inferior recti, with their tendons (2', 3'); 4, capsule of Tenon; 5, sheath of superior rectus, with its orbital prolongation (6); 7, sheath of inferior rectus, with its orbital prolongation (8); 9, inferior oblique muscle, with its orbital prolongation (10); 11, tendon of superior oblique.

extensions of the capsule are prolonged backward upon the muscles for a variable distance, approximately for half their length. The fascial sheaths thus obtained become gradually more and more attenuated in their course toward the origin of the muscles, until finally they fade away by blending with the perimysium. In the case of the superior oblique the tubular prolongation of the capsule extends only over the reflected tendon of the muscle, and terminates at the trochlea, where it ends by becoming attached to the margin of the pulley. The sheath investing the inferior oblique extends as far as the floor of the orbit, and there fuses with that accompanying the inferior rectus.

The inner or ocular border of the vertical slit-like openings through which the tendons of the straight muscles, particularly of the external and

internal, pass, is especially strengthened by thickenings of the fascia, which are further reflected outwardly along the adjacent sides of the tendon-sheaths, forming additional connections between the muscles and the capsule of Tenon. In view of the fact that the latter structure at certain points is firmly connected with the bony walls of the orbit, these supplementary bands in a measure act as pulleys and effect the important object of preventing undue pressure on the eyeball during muscular contraction.

In addition to the foregoing conjunctival and muscular relations, the capsule of Tenon is connected with the orbital walls by means of fascial bands, the most important of which are the suspensory and check ligaments (Fig. 24). The *suspensory ligament* consists of a band of orbital fascia in the anterior part of the orbit, where it forms a hammock-like band of considerable breadth and density; the suspensory ligament is attached mesially to the lachrymal and externally to the malar bone, while its broader central part blends with the capsule of Tenon below the eyeball, to the support and position of which it materially contributes. A somewhat similar but less well-developed band lies above the eyeball and blends with the sheath of the superior rectus and the levator palpebræ; its extension forward coming into close relations with the upper lid. Other fibrous bands stretch across the orbit above the levator palpebræ from the trochlea to the fronto-zygomatic juncture, and thereby form a fascial arch of importance to the support of the upper division of the lachrymal gland.

The *check ligaments* are robust bands which extend from the fascial sheaths surrounding the external and internal recti muscles laterally as far as the malar and lachrymal bones respectively, where they blend with the extremities of the suspensory ligament already described. Their action in limiting the contraction of the outer and inner straight muscles and in preventing excessive rotation of the eyeball is appropriately suggested by their name of "check ligaments." A somewhat similar, but less complete, arrangement exists in connection with the superior rectus, the contraction of which muscle is still further limited by close association with the levator palpebræ. The fascial extension from the sheaths of the inferior rectus is joined by a process from that of the inferior oblique, the two constituting a fibrous band of considerable strength which is attached to the floor of the orbit on the one hand, and blends with the suspensory ligament of the eyeball on the other.

The Lachrymal Apparatus.—The lachrymal apparatus consists of the tear-gland, lodged in the anterior part of the upper and outer orbital wall, and the system of canals by which the tears are conveyed from the inner side of the conjunctival sac to the inferior nasal meatus.

The *lachrymal gland*, resembling in shape and size a small almond, consists of two fairly distinct parts—the superior *orbital* portion and the inferior *palpebral* or *accessory* portion. The former, occupying the fossa lacrimalis, is distinctly larger, and measures about 20 mm. in length, 12 mm. in breadth, and 5 mm. in thickness, just reaching the orbital margin at the point where the roof of the orbit joins the outer wall. The upper convex surface is attached to the periosteum of the depression in which it is lodged. Below the gland is supported by the fascial arch, which extends from the trochlea to the fronto-malar suture.

The lower or *palpebral portion* of the gland, sometimes described as a distinct *glandula lacimalis inferior*, is somewhat smaller than the upper, from which it is partially separated by the fascial expansion already mentioned. Its lower concave surface rests upon the fornix of the conjunctiva and extends laterally almost to the outer canthus.

In structure the lachrymal gland corresponds to a tubulo-racemose gland of the serous type, its acini being drained by a number of small ducts which in the orbital portion of the gland unite to form from three to six larger canals; these receive as tributaries the ducts from the lower portion of the

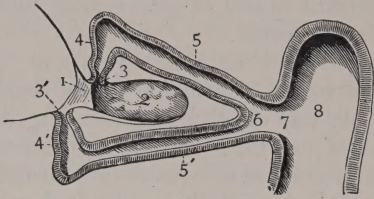


FIG. 25.—Section exposing the lachrymal channels and part of the lachrymal sac (Testut): 1, plica semilunaris; 2, lachrymal caruncle; 3, 3', lachrymal puncta; 4, 4', vertical portions of lachrymal canaliculi; 5, 5', horizontal portions; 6, fused portion; 7, opening into lachrymal sac (8).

gland, the canals so formed opening by distinct orifices arranged with considerable regularity in a line in the fornix. In addition to the chief ducts, which open with definite regularity, a variable number of smaller, independent canals terminate in irregular groups about the apertures of the larger ducts.

The *lachrymal passages* (Fig. 25), including segments of very varying lumen and course, begin at the small crater-like *lachrymal puncta* which surmount the conical *lachrymal papillæ*. The latter elevations occupy the sharply defined margins of the lids just where the mesial end of the arched palpebral borders passes over into the approximately horizontal and more nearly parallel boundaries of the lachrymal lake. The upper punctum lies 6 mm. from the mesial canthus, the lower one being slightly farther removed. The apex of each papilla is directed toward the conjunctival surface, over which it glides during the changes of position of the bulbar conjunctiva occasioned by the excursions of the eyeball. The lachrymal puncta are immersed in the collection of tears occupying the inner angle of the conjunctival sac, and continually carry off the secretion of the tear-gland by capillary attraction. When closely examined the upper and lower papillæ and puncta are seen to vary slightly, the upper papillæ being more slender, higher, and pierced by a punctum about 0.05 mm. less in diameter than that of the lower lid.

In structure the papillæ resemble the adjacent tarsal bands, being largely composed of closely-felted bundles of fibrous tissue, meagerly supplied with blood-vessels, well calculated to resist the action of the orbicular muscle.

The *lachrymal canaliculi*, into which the puncta open, have at first a vertical course; very soon, however, they bend sharply, and continue their converging course generally parallel to the margins of the lachrymal lake as far as the inner canthus, where the canaliculi usually unite in a common canal which almost at once terminates by opening into the lateral and slightly posterior wall of the lachrymal sac. In exceptional cases the canaliculi maintain an independent course, and terminate by separate orifices which open into a diverticulum of the lachrymal sac, the *sinus of Maier*. The entire length of each canaliculus measures from 8–10 mm., the upper canaliculus being longer, more curved, and steeper in its descending course than the lower. The lumen of the canal varies at different points: beginning at the narrow orifice of the punctum, which marks the most constricted point and measuring only 0.1 mm. in diameter, the canal soon widens into a spindle-form dilatation, which is followed by a diverticulum occupying the bend of the canaliculus. The horizontal portion of the canal measures a little over 0.5 mm. in diameter.

The walls of the canaliculi consist of a lining of stratified squamous epithelium supported by a delicate tunica propria rich in elastic fibers; outside, the muscular bundles of the lachrymal portion of the orbicularis palpe-

brarum contribute an additional stratum, and by their sling-like fibers constitute a sphincter around the vertical portion of the canaliculi.

The *lachrymal sac*, into which the canaliculi open, may be regarded as the upper dilated orbital segment of the naso-lachrymal duct, the lower part of which, or the duct proper, traverses the bony canal and opens into the inferior nasal meatus. The length of the sac approximates 12 mm., when distended measuring between 6 and 7 mm. in diameter.

The sac is situated at the side of the nose, near the inner canthus, and lies within the deep lachrymal groove between the superior maxillary and the lachrymal bone; its upper part is embraced externally by the mesial tarsal ligament and some of the inner fibers of the orbicularis palpebrarum, while the orbital surface of the sac is covered by the fibers which spring from the lachrymal bone and constitute the *tensor tarsi*, or *Horner's muscle*. The upper blind end of the sac, or fundus, usually reaches to the level of the upper margin of the tarsal ligament, sometimes a little higher. The lower portion of the sac, between the inferior margin of the tarsal ligament and the commencement of the bony canal, differs materially from the upper in being covered in by comparatively thin and weak structures, the anterior wall of this portion of the sac having the attenuated orbicular fascia alone interposed between the integuments. In consequence of this weakness this point is frequently the seat of dilatations, both normal and pathological; the conspicuous bulging often seen in connection with impeded escape of the tears corresponds to the lower part of the sac, which is unprotected by the dense fibromuscular covering which lies in front of its upper half. The wall of the sac, as well as that of the duct, is composed of fibro-elastic tissue, strengthened by fibrous processes derived from the tarsal ligament. Externally the wall of the sac is loosely connected with the periosteum by fibrous tissue, and therefore capable of distention; internally it is lined by mucous membrane directly continuous with that of the nasal duct. The epithelium covering the mucous membrane of the sac, as well as of the duct, is columnar in type and possesses areas in which cilia are present.

The *nasolachrymal duct*, which constitutes the last segment of the tear-passage, lies within the bony canal formed by the apposition of the superior maxillary, lachrymal, and inferior turbinated bones. The length of the nasal duct is very variable, at times being little over 11 or 12 mm., at others measuring twice as much, the difference being largely due to the manner in which the duct terminates in relation to the nasal mucous membrane, since as much as from 6–8 mm. of its length may be included in the oblique passage through the mucous membrane. The diameter of the nasal duct is from 3–4 mm.; it is not uniform, however, since slight constrictions at its beginning from the sac and about the middle of its course are very frequent. The position of the lower end of the nasal duct also varies, but it is usually about 30 mm. behind the posterior margin of the anterior nasal opening, and about 10 mm. from the front of the inferior turbinal. The direction of this canal, as indicated by the position of probes, varies considerably with regard to the degree of inclination of the course of the canal in relation to both the frontal and sagittal planes. In determining on the living subject the inclination of the canal with the sagittal plane, both Arlt and Merkel regard as trustworthy a comparison of the distance between the middle of the tarsal ligaments of the two sides with the distance between the points where the nasal *alæ* join the cheek. When these measurements coincide the nasolachrymal canal descends vertically; when, as usually, a difference is noted, the deviation from the perpendicular will be equal to half the difference. The direction of

the duct with regard to the frontal plane is best determined, according to Merkel, by a line drawn from the inner canthus to the interval between the second premolar and first molar tooth of the upper jaw. The course of the nasolachrymal duct in general may, therefore, be described as deviating slightly backward from the vertical (Fig. 26).

The mucous membrane of the duct is connected by areolar tissue with the periosteum lining the bony canal, the mucosa, however, being separated from the periosteum by a venous plexus. The exact manner in which the duct opens into the inferior nasal meatus varies: it may terminate as a simple round or elliptical orifice or by an inconspicuous slit-like opening leading obliquely into the mucous membrane. The latter arrangement is sometimes described as forming the so-called *valve of Hasner*, but the presence of a distinct occluding fold must be questioned. The valves described in other parts of the nasal duct consist merely of imperfect, irregular, and inconstant folds of the mucosa, the most constant and best-marked of which lies at the

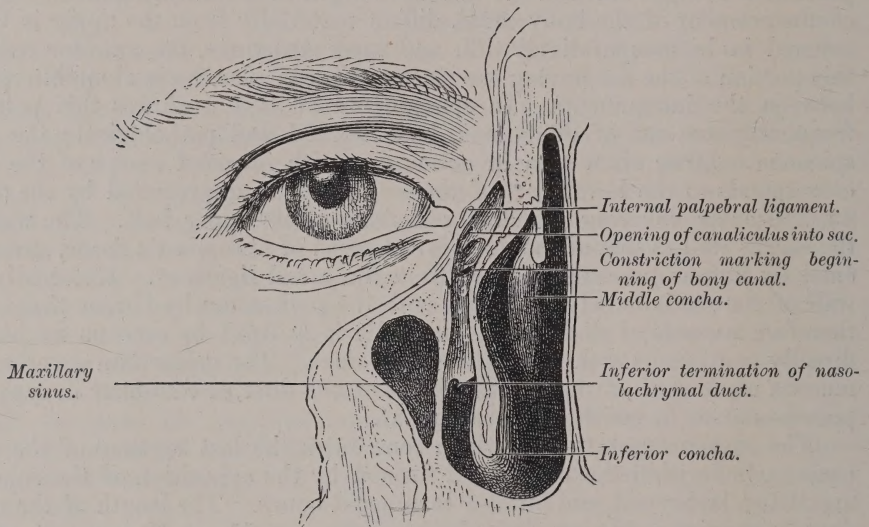


FIG. 26.—Section showing the course and relations of the lachrymal sac and nasolachrymal duct (Merkel).

junction of the lachrymal sac and the duct, which corresponds to the narrowest point of the entire lachrymal canal.

The blood-vessels supplying the lachrymal duct consist of the arterial branches from the nasal and inferior palpebral; the relatively large and numerous veins mostly join the nasal plexus and become indirect tributaries to the ophthalmic and facial.

The nerves distributed to the tear-passages are derived from the infra-trochlear branch of the nasal division of the ophthalmic.

MACROSCOPICAL AND MICROSCOPICAL ANATOMY OF THE EYEBALL.

The general form of the eyeball, as represented by the outlines of its outer fibrous coat, is spherical: when critically examined, however, the anterior segment of the globe presents deviation from the typical form, due to flattening within a zone lying in front of the equator, corresponding to the attachment of the recti muscles, and consequent apparent undue prominence of the corneal segment. In sagittal section the eyeball is seemingly made

up of the segments of two spheres—a larger posterior sclerotic segment, embracing approximately four-fifths of the globe, and a smaller anterior corneal segment, which contributes the remaining portion of the bulb. The junction of these segments is marked by an external broad annular groove, the *sulcus scleræ*, which surrounds the corneal periphery.

The eyeball presents further deviations from the globular form in the inequality of its three principal diameters, the anteroposterior diameter being the longest, the vertical the shortest, and the transverse intermediate. The exact determination of these measurements is by no means a matter of

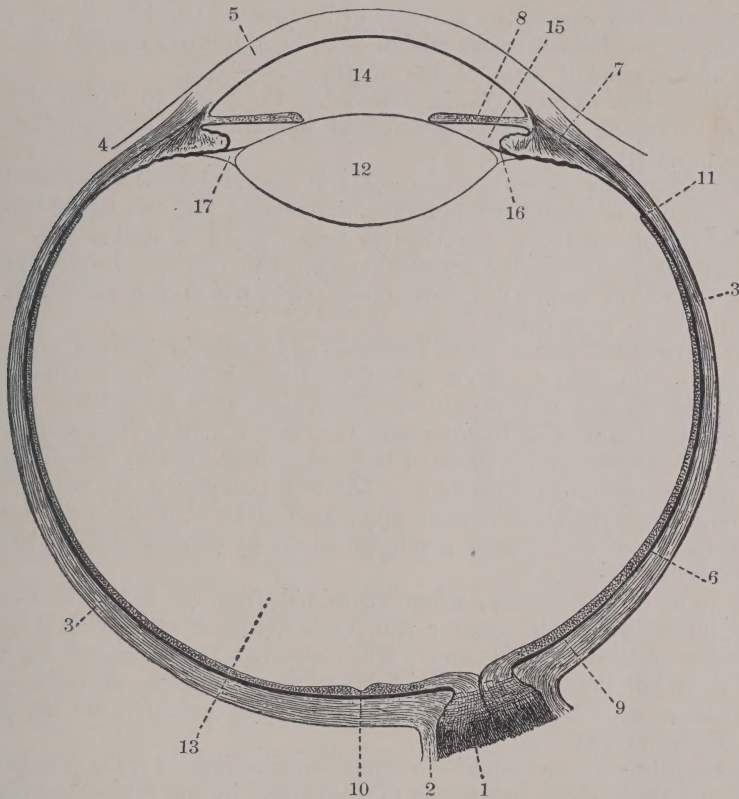


FIG. 27.—Diagram of horizontal section of human eye (Merkel-Raubert): 1, optic nerve; 2, dural sheath; 3, sclera; 4, conjunctiva; 5, cornea; 6, choroid; 7, ciliary body and processes; 8, iris; 9, retina; 10, fovea centralis; 11, ora serrata; 12, lens; 13, vitreous body; 14, anterior chamber; 15, posterior chamber; 16, zone of Zinn; 17, intrazonular cleft.

ease, as is evidenced by the discrepancies in the figures obtained by a number of competent investigators, since variations in the tension, and consequently in the dimensions, of the eyeball are quickly produced by the changes which begin very soon after death. Additional variations are also referable to the deviations in the antero-posterior diameter associated with refractive errors.

The principal diameters of the eyeball in millimeters, based upon the careful and elaborate series of measurements of Sappey, are as follows:

	Male.	Female.	Average.
Antero-posterior diameter	24.6	23.9	24.2
Vertical diameter	23.5	23.0	23.2
Transverse diameter	23.9	23.4	23.6

Approximately, these diameters may be considered for practical purposes as antero-posterior, 24 mm.; vertical, 23; transverse, 23.5. The eyeball may therefore be regarded as a sphere slightly flattened from above downward and from side to side. When directed toward distant objects or in a condition of accommodative rest the axes of the eyes are very nearly parallel; the axes of the optic nerves, on the contrary, are divergent, their entrance lying between 2 and 3 mm. to the inner or nasal side of the point at which the axis of the eyeball meets the posterior wall (Fig. 27).

The eyeball consists of three coats or tunics:

1. The *external fibrous tunic*, of which the sclerotic forms the posterior four-fifths and the cornea the anterior fifth, upon which depend the protection of the more delicate parts within and, to a limited degree, the maintenance of the general form of the organ.

2. The *middle vascular tunic*, embracing the parts to which the chief blood-supply of the eyeball is distributed, including the choroid, the ciliary body, and the iris.

3. The *inner nervous tunic*, which contains the specialized neuro-epithelium for the reception of visual stimulus, the nerve-cells, and the nerve-processes, which, as the nerve-fibers, converge to form the optic nerve.

The *refractive media*, the crystalline lens, the aqueous humor, and the vitreous body, are enclosed within these coats, which the media, in turn, materially aid in supporting.

The Fibrous Tunic.—The Cornea.—The anterior fifth of the eyeball is occupied by the cornea, which structure, although principally composed of closely-felted bundles of dense fibrous tissue, presents a remarkable glass-like transparency, so important in admitting the rays of light to the interior of the ocular bulb. The refractive index of the cornea is about 1.37, or a little above that of water and the aqueous fluid. The transparency of the cornea is preserved only when the close normal apposition of its elements is maintained, any disturbance of the normal arrangement, as by compression, resulting in impaired transparency.

The form of the cornea, when examined from in front, is not quite circular, but elliptical, the greater transverse diameter measuring 11.6 mm., the smaller vertical only 11 mm. The apparent projection of the cornea beyond the sclera depends on a slight flattening of the latter near the equator, rather than on an actual projection of the corneal pole beyond the general sphere of the eyeball.

The curvature of the anterior corneal surface does not accurately correspond to a sphere, since the radius of curvature in the transverse direction (7.8 mm.) is slightly greater than the vertical radius (7.7 mm.); while slight asymmetry of the corneal curvature is probably always present, marked variations are also of frequency and then constitute *astigmatism*.

The form of the inner surface of the cornea, on the contrary, corresponds to a sphere, the radii of curvature being equal in all meridians, and measuring about 6 mm. The discrepancy in the curvatures of the outer and inner corneal surfaces shows that the thickness of the cornea necessarily varies: the cornea is slightly thicker at the periphery, where it measures from 0.9 to 1.1 mm., being from 0.8 to 0.9 mm. thick at the centre.

The corneæ of persons advanced in age usually present the *arcus senilis*, which appears as a narrow gray or yellowish-white crescentic border extending beyond the periphery toward the pupil. Not infrequently a complete ring encircles the corneal limbus, formed by the fusion of the upper and lower crescents. The appearance is due to the infiltration of the corneal

stroma by particles which are usually assumed to be of a fatty nature, although this is questioned by Fuchs, who regards the change as due to a limited hyaline degeneration of the corneal fibers. (See also p. 326.)

The cornea differs from ordinary fibrous tissue in not yielding gelatin on boiling, but a modified form of chondrin.

The structure of the cornea, as seen in vertical section, includes five well-marked layers: these are, from without in—

1. The anterior epithelium;
2. The anterior limiting membrane;
3. The substantia propria;
4. The posterior limiting membrane;
5. The posterior endothelium.

The *anterior epithelium* of the cornea is a direct continuation of the ectodermic covering of the adjacent conjunctiva, and represents one of the few parts of the eye derived from the outer embryonic layer. The epithelium is stratified squamous in type, and thinnest over the central part of the cornea, the six to eight layers in this position together measuring about 0.045 mm.; at the periphery the epithelium is almost twice as thick. The deepest cells approach the columnar form, their bases, often somewhat extended, resting upon the anterior limiting membrane, while the outwardly-directed rounded ends are received between the cells of the more superficial strata. The elements composing the middle layers are polyhedral in form, and often present the appearance of prickles-cells. The cells of the superficial strata and free surface are greatly flattened and lie parallel to the free surface (Fig. 28).

The *anterior limiting membrane*, *membrane of Bowman*, or *lamina elastica anterior*, is conspicuous in the human cornea and represents a highly developed basement-membrane. This layer appears as a homogeneous glassy band, about 0.002 mm. in thickness, immediately beneath the epithelium; it is thickest at the center and thinnest at the corneal periphery. The membrane is resolvable into the fibrous fibrillæ upon the application of suitable reagents, thus demonstrating its true nature as a localized condensation of the fibrous corneal stroma, of which it is a specialization.

The *substance proper* constitutes the chief bulk of the cornea, and is composed of the fibrous stroma, which is built up of innumerable interlacing bundles of fibrous tissue. The interlacing fibrous bundles are disposed with some regularity as lamellæ, although the exact number and arrangement of these are variable. The fibrillæ of fibrous tissue, as well as the bundles, are held together by the interfibrillar cement substance, which likewise aids in joining the lamellæ. The fibrous bundles

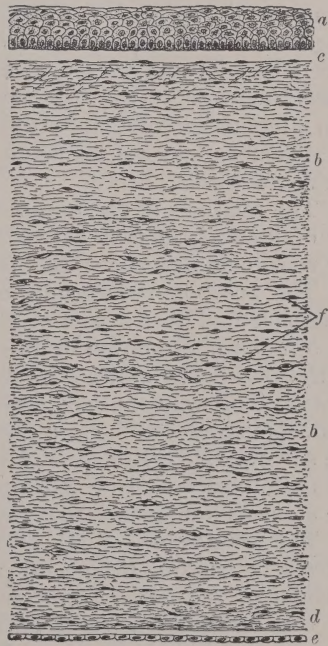


FIG. 28.—Section of cornea (Piersol): a, anterior epithelium; c, anterior limiting membrane; b, b, fibrous stroma of substantia propria, containing corneal corpuscles (f) lying within the corneal spaces; d, posterior limiting membrane; e, endothelium lining anterior chamber.

cross one another at various angles, and are often united by bands which pass between the adjacent bundles; these *fibræ arcuatae* are especially conspicuous in the anterior lamellæ. The peculiarity of the substantia propria in yielding after boiling a modified form of chondrin, instead of the usual gelatin, has already been mentioned.

The *cellular elements*, the *corneal corpuscles*, are flattened, plate-like connective-tissue cells which lie between the lamellæ of the fibrous stroma within the intercommunicating lymph-spaces hollowed out within the cement substance. The corneal cells are irregularly branched, and form, by means of their united processes, a protoplasmic network throughout the corneal stroma. The corneal spaces in which the cells lie are larger than the cells, and are therefore only partially filled by the protoplasmic elements, the unoccupied space affording channels for the circulation of the nutrient tissue-juices upon which the investment of the non-vascular cornea depends. Communication between the corneal spaces is established by the canaliculi which pass from one space to the other. The corneal cells usually are applied to one wall of the spaces, and, in principle, resemble the endothelial plates which line other and larger lymphatic cavities. Occasional migratory leukocytes, or *wandering cells*, are also found within the system of corneal juice-channels.

The *posterior limiting membrane*, *membrane of Descemet*, *membrane of Demours*, or *posterior elastic membrane*, appears as a sharply-defined homogeneous band from 0.010 to 0.012 mm. in its thickest peripheral portion, at the inner boundary of the substantia propria. It differs from the anterior limiting membrane in its marked resistance to acids, alkalies, boiling water, and other reagents; it resembles, but is by no means identical with, elastic tissue. It is capable of complete separation from the substantia propria after prolonged maceration in a 10 per cent. solution of sodium chlorid. The layer in question contains no cells, and ordinarily presents no indication of being composed of secondary lamellæ, although sometimes after reagents it shows traces of such structure.

The relations of the posterior limiting membrane at the corneal periphery are of interest, since in this position it breaks up into numerous bands which are continued into the trabeculæ forming the pectinate ligament of the iris.

The *posterior endothelium* covers the inner surface of the membrane of Descemet and forms part of the lining of the anterior chamber of the eye. This innermost stratum of the cornea is composed of a single layer of polyhedral plates, the outlines of which constitute a mosaic of considerable regularity. The cells closely resemble ordinary endothelial plates, possessing oval, sometimes reniform, nuclei which are usually of greater thickness than the surrounding cell-body. The endothelium and the membrane of Descemet are of importance as constituting almost impassable barriers to the escape of the aqueous humor into the lymph-channels of the cornea.

The *blood-vessels* of the normal fully-developed cornea are limited to an extremely narrow peripheral zone, about 1 mm. in width, the remaining portions of the cornea being entirely devoid of blood-channels. The vascular zone contains the terminal loops of the episcleral branches derived from the anterior ciliary arteries. The venous radicles become tributaries of the anterior ciliary veins.

The *nerves* of the cornea constitute a rich supply arranged in the form of numerous plexuses. The corneal nerves are derived from the ciliary plexus, contributed by the long and short ciliary nerves, and form an annular plexus in the vicinity of the corneal margin. The twigs from the annular plexus pass either directly or indirectly to the corneal tissue, those destined for the

anterior layers first having joined the conjunctival nerves before proceeding to the cornea. The more numerous branches which pass directly to the corneal stroma from the annular plexus enter the substantia propria near the posterior limiting membrane, the far greater number, however, passing to the anterior lamella, only about one-third of the nerves which enter the cornea being distributed to the posterior layers. The nerve-bundles, on penetrating into the corneal stroma, are invested for a short distance, from 0.75–1 mm., by perineural lymph-sheaths, the individual nerve-fibers losing their medullary sheaths at about the same time.

After entering the substantia propria the nerves form the *fundamental plexus* within the corneal stroma, from which numerous lateral branches are given off at various levels; these are composed of non-medullated fibers which soon break up into the component varicose fibrillæ. In addition to the lateral twigs, *perforating branches* ascend through the anterior lamellæ as far as the epithelium, beneath which they form the *subepithelial plexus*. The terminal fibers of this plexus in many instances enter the epithelium to end either in special end-bulbs or between the cells as the *intra-epithelial plexus*. The plexuses within the substantia propria formed by the twigs given off at various levels spread out between the lamellæ of fibrous tissue; the nodal points or places of meeting of the fibers are often marked by angular areas outlined by the interlacing fibers; nuclei, belonging to the delicate nerve-sheaths, are sometimes present. The terminal fibers of the corneal nerves are related to various forms of end-organs, among which are intricate *convolutions*, less-contorted *loops* and *hooks*, and irregular quadrate *plates*.

The Sclera.—The sclerotic coat forms the posterior four-fifths of the fibrous tunic of the eyeball, contributing largely to the protection and support of the more delicate structures within, as well as affording the points of attachment of the ocular muscles. Although composed of practically the same histological elements as the cornea, the disposition of these is such that the dead-white opacity is produced which so conspicuously contrasts with the beautifully transparent cornea.

The sclera is thickest over the posterior third of the ball, where the maintenance of a uniform curvature for the support of the retina is of great importance: in the vicinity of the optic nerve the sclerotic coat measures nearly 1 mm. in thickness, gradually becoming thinner toward the anterior boundary, until beneath, or just posterior to, the zone of attachment of the recti muscles the sclera is reduced to about 0.4 mm. Anterior to the tendon-zone the thickness of the fibrous tunic is augmented by the expansion of the muscle insertions until it reaches about 0.6 mm. In individuals possessing thin scleræ and deeply pigmented eyes the sclerotic coat presents a bluish or skimmed-milk tint, due to the deeply-colored tissue beneath the fibrous coat; this bluish appearance is well marked in the eyes of young children.

In its structure the sclera closely resembles the cornea, being composed of interlacing bundles of fibrous tissue disposed with much greater irregularity, however, than those of the cornea. The clefts between the fibrous bundles correspond to the corneal spaces and contain irregularly stellate connective-tissue cells—the *scleral corpuscles*. The scleral spaces are less regularly arranged and possess a less elaborate system of connecting canaliculi. The scleral bundles further differ from those of the cornea in containing numerous elastic fibers and in yielding gelatin on boiling: their general disposition is equatorial and meridional, although the bundles interlace with one another at all angles.

In addition to the usual branched scleral corpuscles, those occupying the

innermost stratum are deeply pigmented, in consequence of which the inner surface of the sclerotic coat presents a dark color and is known as the *lamina fusca*: this layer constitutes the outer wall of the subscleral lymph-space, and is attached to the subjacent choroid by numerous trabeculæ, which, together with the limiting walls of the space, are covered with endothelial plates. The greater extent of the outer surface of the sclera, from the sheath of the optic nerve to the insertion of the ocular muscles, is also clothed with endothelium, which forms part of the lining of the episcleral space of Tenon.

The *blood-vessels* of the sclera, in addition to the perforating vessels, which include anterior branches from the anterior ciliary vessels, the large equatorially situated *venæ vorticosæ*, and posterior branches from the posterior ciliary vessels, are represented by the meager twigs within the superficial strata of the fibrous tunic derived from the wide-meshed episcleral network formed by branches derived from the anterior and posterior ciliary arteries. The sclera receives additional branches from the short ciliary arteries in the vicinity of the optic entrance: these small vessels are of interest, since from the *circulus Zinnii*, which they form within the fibrous coat around the optic nerve, minute twigs extend into the dural nerve-sheath and anastomose with the arterioles supplying the sheath derived from the central artery of the retina, thus establishing a communication between the retinal and choroidal circulation.

The veins which drain the scleral coat are tributary to three sets of vessels: those from the anterior tract, emptying into the anterior ciliary veins; those from the equatorial zone, joining the *venæ vorticosæ*; and those from the posterior part, pouring their blood into the posterior ciliary veins.

The *lymphatics* of the sclera are represented by the system of intercommunicating scleral spaces, those in the vicinity of the sclero-corneal juncture being in close relation with the spaces of Fontana at the angle of the anterior chamber, which they indirectly aid in draining.

The *nerves* distributed to the sclerotic coat consist of a few twigs derived from the ciliary nerves as these pass between the sclera and choroid, which terminate between the fibrous bundles of the superficial layers as tortuous and intricately coursing ultimate fibrillæ.

The relations of the scleral tissue to the sheaths surrounding the optic nerve will be considered with the description of the Optic Entrance.

The Sclero-corneal Juncture.—The position at which the sclera and corneal segments of the fibrous coat meet is one of the most important regions of the eye, since in the immediate vicinity of this junction lie important channels through which escapes the aqueous humor as well as the fibers giving origin to the ciliary muscle.

The conspicuous line of union between cornea and sclera depends far more upon the physical differences of the two portions of the fibrous coat than upon actual structural variation, since the elements are not only almost identical, but directly continuous. When seen in section the scleral tissue extends along both margins farther forward than does the corneal substance, the effect of this arrangement being to receive the cornea with an apparent annular groove bounded by the *outer* and *inner scleral processes*: of these the inner is shorter and does not reach as far toward the anterior pole as the outer.

The connections of the inner scleral process are of especial importance on account of the relations to the structures marking the meeting of the cornea, the iris, and the ciliary muscle. Just anterior and external to the

inner scleral process a distinct, usually somewhat irregularly elliptical, opening indicates the position of the annular venous sinus, the *canal of Schlemm* (Fig. 29). This channel, also called the *circulus venosus ciliaris*, as seen in meridional sections, elliptical or pyriform in its transverse figure, measures about 0.3 and 0.045 mm. in the longest and shortest diameters respectively. The walls of the canal of Schlemm differ greatly in character, the outer boundary being dense, while the inner is composed of a spongy reticulated layer, apparently the continuation of the inner scleral process. The inner wall is closely united with the posterior limiting membrane of the cornea anteriorly, and internally with the pectinate ligament of the iris and meridional fibers of the ciliary muscle.

The character of Schlemm's canal, whether a venous or lymphatic channel, was long a subject of active controversy: the recent investigations of Leber, however, have brought the formerly opposed views into harmony by showing that the conflicting evidence, based upon carefully conducted observations, was due to conditions of intraocular tension under which the experiments were carried out. It may be regarded as definitely established that the canal of Schlemm is an annular venous sinus which by means of the spaces of Fontana stands in close relation to the anterior chamber on the one hand, and directly communicates with the anterior ciliary veins on the other. Under usual conditions Schlemm's canal contains but little blood—a fact which is explained by Schwalbe upon the supposition that the sinus is an annular reserve diverticulum for the reception and storage of blood when for any reason there is a temporary retardation to the escape of the blood passing through the anterior ciliary veins; the narrowness of the communicating branches between Schlemm's canal and the scleral veins under ordinary conditions favoring the more direct passage of the contents of the scleral veins into the anterior ciliary vessels, rather than its entrance into the canal.

The tissue forming the wall of the anterior chamber at its angle, occupying the space between it and the canal of Schlemm, is peculiar in character, being composed of an aggregation of interlacing trabeculæ composing a spongy mass containing interfascicular clefts, the *spaces of Fontana*. These spaces constitute a system of intercommunicating lymph-channels which are imperfectly lined with endothelial plates and freely communicate with the anterior chamber, the aqueous humor filling the spaces.

The spongy tissue containing the spaces of Fontana collectively constitutes an annular prismoidal mass, the apex of which begins at the corneal margin, where the membrane of Descemet splits up into delicate bands: these bands mark the origin of the trabeculæ which pass toward the iris and constitute the *ligamentum pectinatum iridis*, a rudimentary structure in man representing the much more conspicuous series of conical processes extending from the iris toward the cornea in ruminants. The imperfect character of the endothelial lining of the spaces of Fontana allows the ready entrance of the lymph contained within the anterior chamber, so that the clefts between the trabeculæ are filled with the escaped aqueous humor; the loose nature of the septum forming the inner wall of Schlemm's canal is also favorable to the passage of fluids, in consequence of which arrangement the aqueous humor is continually passing, under normal conditions of intraocular tension, through the spaces of Fontana into the canal of Schlemm, and thence into the communicating venous radicles. This exit for the intraocular lymph is of the utmost importance in maintaining an equilibrium of tension within the eyeball.

The Vascular Tunic.—The *middle* or *choroidal* coat of the eyeball, distinguished by its dark color, and therefore often called the *uveal tract*, is essen-

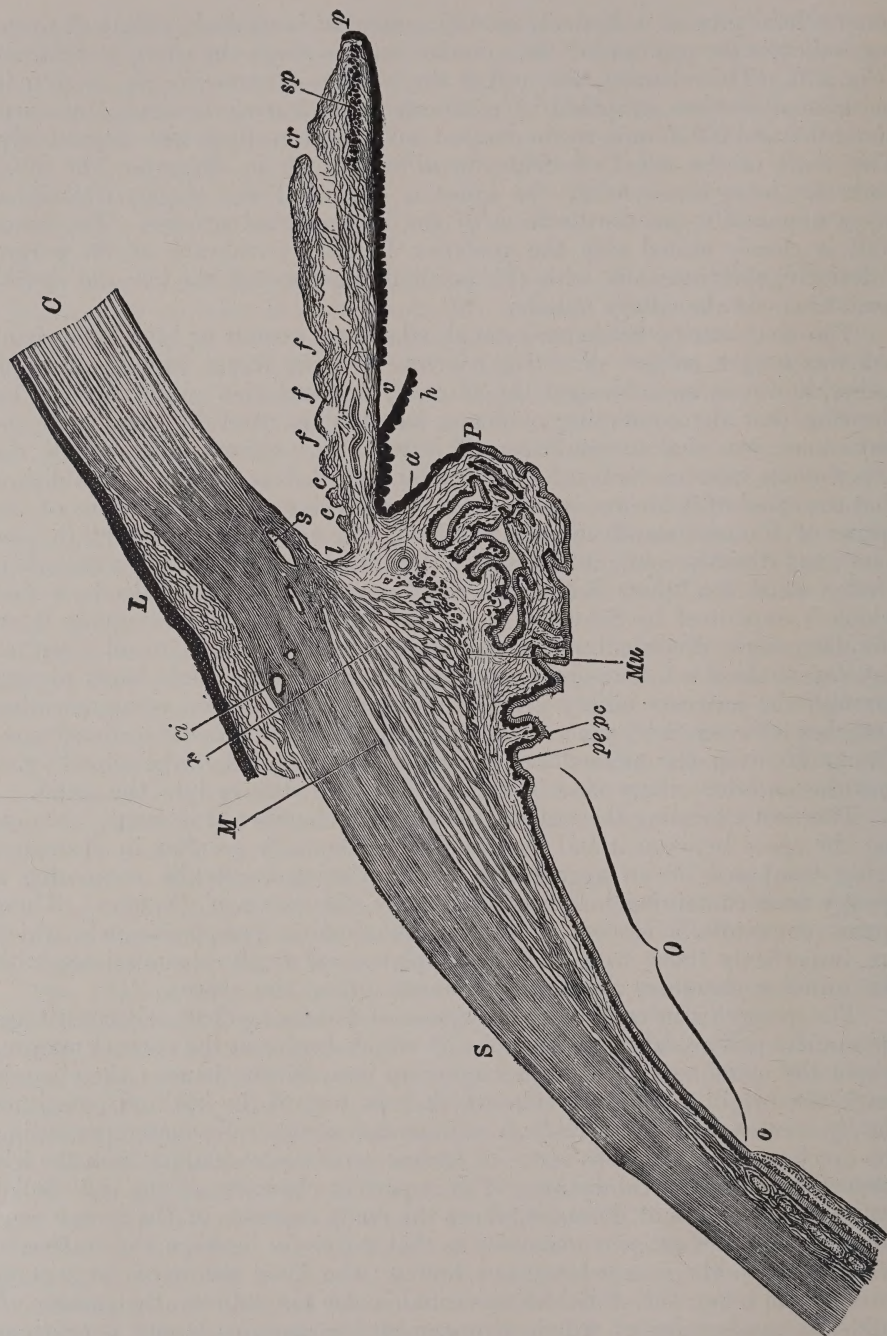


FIG. 29.—Section through ciliary region, including part of cornea and sclera, the iris, ciliary process, and muscle (Fuchs) *C*, cornea; *S*, sclera; *M*, ciliary muscle; *r*, radiating fibers; *Mu*, circular fibers of Müller; *pe*, *pc*, pigmented and non-pigmented cells of pars ciliaris retinae; *ci*, anterior ciliary artery; *s*, canal of Schlemm; *z*, origin of ciliary muscle; *ce*, *ff*, folds of anterior surface of iris; *cr*, artificial break in iris; *sp*, sphincter pupillae; *p*, pupillary border of iris; *h*, pigment partly detached from iris; *P*, ciliary process; *O*, ciliary ring; *o*, ora serrata.

tially a sheet of vascular connective tissue. It includes three distinct portions—the choroid, the ciliary region, and the iris—and extends from the optic nerve

to the pupil. The character of its component structures renders the nutritive coat soft, friable, and extensible, and, owing to the presence of muscular tissue within its ciliary and iridial segments, it is subjected to constant variations in its tension. The blood-vessels of this tunic constitute the chief nutritive apparatus of the eye, since the functionally most active portions of the organ, as the percipient layers of the retina and the ciliary muscle, receive their nutrition from this source.

The choroid constitutes the posterior two-thirds of the vascular tunic, extending from the optic-nerve entrance to the anterior limit of the visual portion of the retina, or ora serrata, lying closely united to the functioning segment of the nervous tunic, to the nutrition of which it ministers. The thickness of the choroid gradually diminishes toward the ora serrata, being about 0.1 mm. near the nerve and 0.06 mm. at the ora serrata. While applied to the inner surface of the sclera the union between the two coats is not firm, since the opposed surfaces, covered with endothelium, are separated by the intervening *suprachoroidal lymph-space*; irregular trabeculæ extend across this space, and, in addition to attaching the sclera and choroid imperfectly, subdivide the cleft into numerous secondary compartments. When separated from the fibrous coat the outer surface of the choroid appears rough

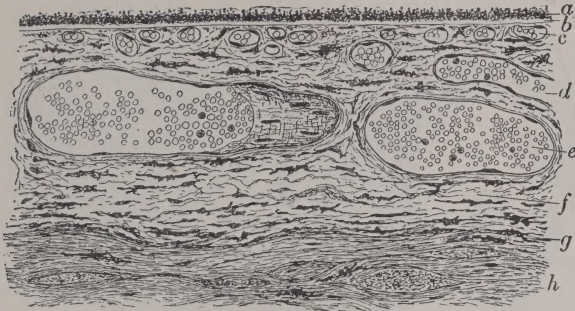


FIG. 30.—Section of human choroid (Piersol) : *a*, retinal pigment adhering to vitreous membrane (*b*); *c*, capillary layer, or chorio-capillaris; *d*, *e*, large blood-vessels of stroma layer; *g*, lamina suprachoroidea; *h*, tissue of sclera.

and ragged, owing to the adherent torn trabeculæ. The suprachoroidal space is also occupied by the large vascular and nervous trunks which traverse the cleft in their course to other parts of the eyeball; those which pierce the sclera, as the *venæ vorticosæ*, aid in further uniting the vascular and fibrous tunics. The inner surface of the choroid, on the contrary, is very intimately united with the adjacent pigmented layer of the retina; so that the latter often adheres to the choroid when the middle coat is removed.

The choroid consists of a more or less compact connective-tissue stroma, which supports numerous blood-channels of very varying size; the arrangement of these vessels largely determines the peculiarities of the layers into which the choroid is divided (Fig. 30). These are three :

1. The layer of choroidal stroma containing blood-vessels of large size;
2. The layer of dense capillary networks—the chorio-capillaris;
3. The homogeneous glassy lamina or membrana vitrea.

The loose layer of trabecular bands connecting the outer surface of the choroid and the inner surface of the sclera constitutes the *lamina suprachoroidea*, sometimes described as an additional layer of the choroid. The membrane-like trabeculæ consist of interlacing fibro-elastic bundles, upon

the surface of which lie the flattened, irregularly-branched pigmented connective-tissue cells, the deeply-pigmented protoplasm rendering them conspicuous elements.

The *choroidal stroma* consists of a ground-substance of closely interwoven connective-tissue lamellæ, which support the blood-vessels. The structural elements include the usual bundles of white fibrous tissue, numerous elastic fibers, and stellate pigmented cells; the stroma is especially dense in the immediate vicinity of the blood-channels.

The layer containing the large blood-vessels constitutes the larger part of the choroid, the vascular canals appearing as apertures and lighter channels within the darker choroidal stroma. The largest vessels occupy the most superficial or outer stratum of the choroidal stroma, those of medium size the

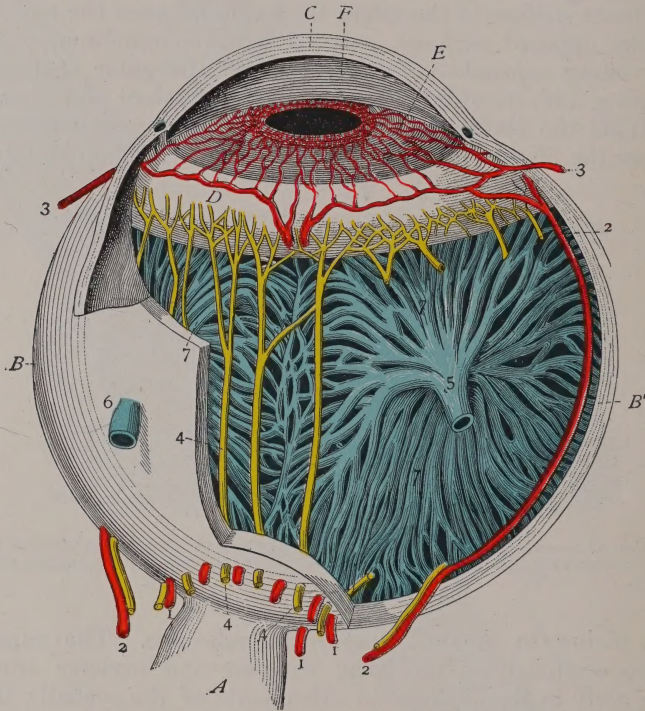


FIG. 31.—Diagrammatic view of principal blood-vessels and nerves of the eyeball (Testut): A, optic nerve; B, sclera; B', viewed in section; C, section of cornea; D, ciliary muscle; E, iris; F, anterior chamber; 1, short posterior ciliary arteries; 2, long posterior ciliary arteries; 3, anterior ciliary arteries; 4, ciliary nerves; 5, one of the large venæ vorticosæ; 6, vena vorticiosa after piercing the sclera; 7, vasa vorticiosa of the choroidal tunic.

middle layer, while the innermost layer is devoted to the capillary network, the *chorio-capillaris*.

The most conspicuous of the large superficial blood-channels are the four venous trunks, the *venæ vorticosæ*; these pierce the choroid within the equatorial zone at points about equidistant and establish foci toward which the smaller veins within each quadrant converge; these tributaries form peculiar venous whorls within the superficial layers of the choroidal stroma (Fig. 31). The venæ vorticosæ traverse the suprachoroidal space, invested by a partial envelope contributed by the lamina suprachoridea, and pierce the sclera, running obliquely backward. Perivascular lymph-sheaths usually invest the venous trunks within the choroid. The arteries within the choroidal stroma

possess longitudinally disposed muscle-bundles in addition to the customary circular fibers.

A narrow *boundary-zone* separates the layer containing the large veins from the capillary stratum: it consists of closely felted fibro-elastic fibers intermingled with sparingly distributed connective-tissue cells devoid of pigment. In many animals, as the horse, cow, or sheep, the boundary-zone contains many bundles of dense connective tissue, which arrangement produces the peculiar metallic reflex sometimes seen in such eyes; this shining layer constitutes the *tapetum fibrosum*, as distinguished from the *tapetum cellulosum* of the carnivora, which structure depends upon the presence of several layers of cells containing minute crystals.

The inner capillary zone of the choroid, the *chorio-capillaris* or *membrane of Ruysch*, occupies the inner portion of the vascular tunic lying next the vitreous membrane, which alone separates the rich vascular layer from the nervous coat, to the nutrition of which it so largely ministers. The capillaries are unusually uniform in size, measuring about 0.009 mm. in diameter; the meshes of the network are very small, even surpassing in closeness those of the lungs, being only 0.01 to 0.02 mm. in the macular region, and about 0.02 to 0.03 mm. toward the ora serrata. The red reflex seen in the eye when viewed with the ophthalmoscope is due to the reddish color of this vascular layer showing through the retina.

The *vitreous membrane*, *lamina basilaris*, *membrane of Bruch*, or *lamina vitrea*, constitutes the inner boundary of the choroid, lying next the nervous tunic, which it separates from the chorio-capillaris. The membrane represents a specialized condensation of the choroidal stroma, and appears as a homogeneous zone which measures only 0.002 mm. in thickness.

The *nerves* of the choroid are derived from branches given off from the long and short ciliary nerves during their course between the vascular and fibrous tunics. The choroidal nerves, which are both medullated and non-medullated, form a wide-meshed plexus within the lamina suprachoroidea containing groups of ganglion-cells. From this plexus numerous slender, non-medullated fibers proceed to the arteries, the muscular tissue of which they especially supply; isolated or very limited groups of ganglion-cells are found along the blood-vessels.

The *lymphatics* of the choroid are probably represented by distinct capillary vessels which communicate with the lymph-spaces between the channels of the chorio-capillaris on the one hand, and the perivascular sheaths tributary to the larger lymph-canals on the other.

The *ciliary body* includes the middle segment of the vascular tunic, extending from the ora serrata behind to the sclero-corneal juncture in front. As seen in meridional sections, this region appears as a triangle, the longer and outer side of which lies next the sclera and sclero-corneal juncture, the short anterior side against the pectinate ligament, and the inner margin in apposition with the irregular, deeply pigmented extension of the retinal tunic.

The ciliary body presents three subdivisions—the ciliary ring, the ciliary processes, and the ciliary muscle.

The *ciliary ring*, or *orbiculus ciliaris*, includes the smooth annular tract lying between the sinuous border of the ora serrata behind and the ciliary processes in front, constituting a band about 4 mm. in width. This zone differs in its structure from the choroid proper, chiefly in the absence of the rich vascular supply, since the capillary layer ceases at the ora serrata, or at the point where the percipient elements of the nervous tunic end for whose

nutrition the chorio-capillaris is especially designed. The larger blood-vessels of the choroid are here represented by the venous trunks which return the blood from the iris and ciliary processes and proceed as tributaries to the *venæ vorticosæ*. When viewed from the posterior surface the ciliary ring presents numerous delicate radial striations: these are due partly to the blood-vessels and partly to minute plications of the surface, best marked toward the anterior boundary of the ring.

The *ciliary processes* appear on the posterior surface of the ciliary region as an annular series of pyramidal folds, about seventy in number, the conspicuous projecting bases of which encircle the attached border of the iris, while their apices gradually fade away in the orbiculus ciliaris. The delicate radial striations seen on the surface of the latter are so related to the ciliary processes that each projection seemingly begins by the fusion of several striations, and rapidly increases in breadth and height to a point opposite the margin of the crystalline lens, and then abruptly diminishes to the level of the iris. The elevations measure between 2 and 3 mm. in length, 0.12 to 0.15 mm. in breadth, and in their boldest part from 0.8 to 1 mm. in height. The processes consist chiefly of convoluted blood-vessels supported by delicate connective-tissue stroma, and covered by the pigmented extension of the retinal tunic, the *pars ciliaris retinæ*. It is probable that the particular function of the ciliary processes, in addition to affording attachment for the fibers of the suspensory ligament of the lens, is the secretion of the aqueous humor, to which end their peculiar formation and unusual vascularity are especially adapted.

When seen in meridional sections each process is observed to be composed of a number of irregular projections, varying greatly in size and arrangement (Fig. 29); in general, the maximum elevation marks the inner angle next the iris, from which point they gradually diminish toward the orbicular ring, where they fade away. In addition to the connective-tissue stroma containing the rich convolution of blood-vessels, the inner surface of the ciliary processes, as well as that of the orbiculus ciliaris, is covered by a continuation of the vitreous membrane of the choroid, which in this region is somewhat thickened, measuring from 0.003 to 0.004 mm.; this limiting membrane separates the stroma of the ciliary process from the retinal layer represented by the double stratum of epithelial cells which covers the inner surface of the projections.

The *ciliary muscle* is very conspicuous in meridional sections of the eyeball, then appearing as a triangular fold of involuntary muscle and connective tissue which lies between the sclera and the proper tissue of the ciliary processes. In its entirety the ciliary muscle forms a prismoidal annular band which surrounds the angle of the anterior chamber and attached margin of the iris.

The muscular area consists of three sets of bundles of involuntary muscle, intermingled with connective tissue, arranged as *meridional*, *radial*, and *circular* fibers. The meridional bundles are closely grouped and constitute a compact muscular layer next the sclera, to which they are loosely connected by fibers of the lamina suprachoroidea. These muscular bundles take origin from the inner scleral process and tissue, forming the inner wall of Schlemm's canal; posteriorly, the meridional bundles are attached to the choroidal tract, into which they are inserted by delicate tapering processes; from their relation to the vascular tunic the meridional muscular bundles are often called the *tensor choroidea*. The typical meridional fibers lie next the sclera; those more internally situated gradually assume a more radial

disposition, and insensibly blend with those whose course is such that they constitute the radial group (see Fig. 29).

The radial fibers of the ciliary muscle are less closely placed than the meridional, and form a reticulum in which the muscular bundles are separated by a considerable amount of intervening connective tissue. The fan-shaped mass of radial fibers diverges from their point of origin from the membrane of Descemet and inner wall of Schlemm's canal, the innermost fibers passing toward the ciliary processes and the outer to the anterior border of the orbiculus ciliaris.

In addition to the meridional and radial bundles an isolated group of circularly disposed muscular fibers occupies the inner angle of the triangular field formed by the ciliary muscle at the base of the iris; these fibers constitute the *circular or ring muscle of Müller*.

The general form of the ciliary muscle in the emmetropic eye approximates a right-angled triangle, the hypotenuse corresponding to the long scleral margin: in the markedly abnormal refractive conditions of myopia and hypermetropia the circular fibers are respectively atrophic or over-developed, which results in the obtusely-angled myopic muscle and the unusually acute-angled muscle of the hypermetropic eye.

The *blood-vessels* of the ciliary body are derived from the anterior and long ciliary arteries, which form around the root of the iris the anastomotic ring, the *circulus iridis major*. In their course through the ciliary muscle to gain the periphery of the iris these vessels give off twigs which pass directly to the muscle-substance; the arteries supplying the ciliary processes pass backward from the *circulus iridis major*, piercing the inner part of the muscle to reach the anterior extremities of the elevations.

The *veins* returning the blood from the ciliary muscle pass principally into the anterior ciliary trunks: additional venous radicles, however, convey a part of the blood in the opposite direction to join that returned from the ciliary processes by the posteriorly coursing vessels, which finally become tributary to the great equatorial veins.

The *nerves* of the ciliary body include sensory, motor, and sympathetic fibers derived from the anterior branches of the long and short ciliary trunks; these nerves form an annular plexus, the *orbiculus gangliosus*, within the ciliary muscle. Four sets of fibers probably exist within the ciliary body: 1, sensory fibers, largely subcleral in distribution; 2, vaso-motor fibers distributed to the walls of the blood-vessels; 3, motor fibers ending within the muscular tissue of the ciliary body; 4, fibers terminating within the inter-fascicular tissue of the ciliary muscle.

The iris constitutes the anterior segment of the vascular tunic, and is visible, on looking through the clear cornea, as the delicate, contractile, variously tinted septum which contains the central aperture or *pupil*. The plane of the iris is not quite vertical, as its pupillary margin rests upon the anterior surface of the lens, which causes slight convexity of its plane. The thickness of the curtain is about 0.04 mm. in the quiescent condition, in a widely dilated state being nearly doubled. The diameter of the iris is about 11 mm., of which the pupil appropriates from 3-6 mm. when at rest (see also p. 147).

The attached or ciliary border of the iris joins the ciliary body behind, and is continuous with the membrane of Descemet through the pectinate ligament in front; its zone of attachment lies about 3 mm. behind the apparent corneal margin as viewed from before. The exact outline of the thin pupillary border is difficult to see, owing to its intense black color due to

the deeply pigmented tissue which forms the immediate boundary of the opening: critically examined, it presents a slightly irregular or dentated contour.

The *color of the iris*, as viewed from the anterior surface, varies greatly, and depends for its production upon two factors—the deeply pigmented cells covering the posterior surface of the iris as well as lining the pupillary opening, and the amount of pigment contained within the iridial stroma. When the pigmented stroma-cells are very few or absent the dark color of the posterior layer shines through the thin stroma, and the iris appears blue; when the stroma is thicker the tint becomes modified to gray. With the presence of additional pigment within the stroma varying deeper shades, as green, hazel, brown, are produced; finally, when the stroma is laden with pigmented cells, the darkest tints of brown appear—the so-called “black eyes” (see also page 147).

The color is not uniform, but is distributed in irregular spots and patches, sometimes of fanciful form, of lighter and darker tints, so that a definite tint is produced only on viewing the iris at a distance sufficient to blend the variously tinged areas. Close examination shows a further disposition of the color in two zones concentric with the pupil—the *pupillary*, from 1–2 mm. wide, which is lighter in dark eyes and darker in light eyes, and an outer or *ciliary*, from 3–4 mm. in width, which is darker in dark eyes and lighter in light eyes. The boundary-zone between the two is often marked by a series of festoon-like ridges, the *circulus minor iridis*.

The *anterior surface* of the iris, when viewed from before, exhibits a distinct sculpturing consisting in numerous radial striate ridges; these are particularly fine and closely approximated within the pupillary zone, where they unite toward the inner margin, leaving deep intervening clefts. The broader ciliary portion is subdivided into three secondary zones concentric with the pupil—an inner *smooth* ring, not plicated during dilatation of the pupil; a middle *furrowed* band; and an outer irregularly pitted *marginal* or *cribriform* zone. The first two are visible in the living eye, the third is covered by the scleral border.

The *posterior surface* of the iris presents numerous radially arranged ridges separated by intervening furrows, which are intersected by concentric lines; within the pupillary zone the concentric markings almost disappear, while the radial are more numerous than elsewhere, resulting in the apparent plication of the inner zone of the iris.

The form of the human pupil is normally circular under all conditions of contraction; in marked contrast are the elliptical or slit-like pupils of many mammals, in some of which, as the horse and ox, the long axis of the contracted pupil is horizontal; in others, as the cat and tiger, vertical.

The structure of the iris, as seen in radial sections, presents two chief layers—the iridial stroma proper and the pigment layer; these include five sub-layers (Fig. 32):

1. Anterior endothelium;
2. Anterior boundary layer;
3. Vascular stroma layer;
4. Posterior limiting layer;
5. Pigment layer.

Reference to the development of the iris shows that the pigment layer is the contribution of the nervous tunic, and morphologically represents the anterior edge of the secondary optic vesicle, derived from the ectoderm, while the remaining parts of the iris are mesodermic in origin.

The *anterior endothelium* forms part of the lining of the anterior cham-

ber, and consists of a single layer of irregular polygonal plates, directly continuous with those covering the posterior surface of the cornea.

The *anterior limiting membrane* does not exist as a distinct layer, being simply the modified and condensed subendothelial stratum of the general stroma into which it blends. The connective-tissue cells are here unusually closely placed, with a corresponding meagerness of the intercellular fibrous tissue; minute interfascicular clefts represent a system of intercommunicating lymph-spaces. Blood-vessels are wanting within this part of the iris.

The *vascular stroma* layer, forming the bulk of the iris, consists of a loose connective tissue supporting the numerous blood-vessels and nerves which occupy this stratum, and enclosing interfascicular lymph-spaces, as well as

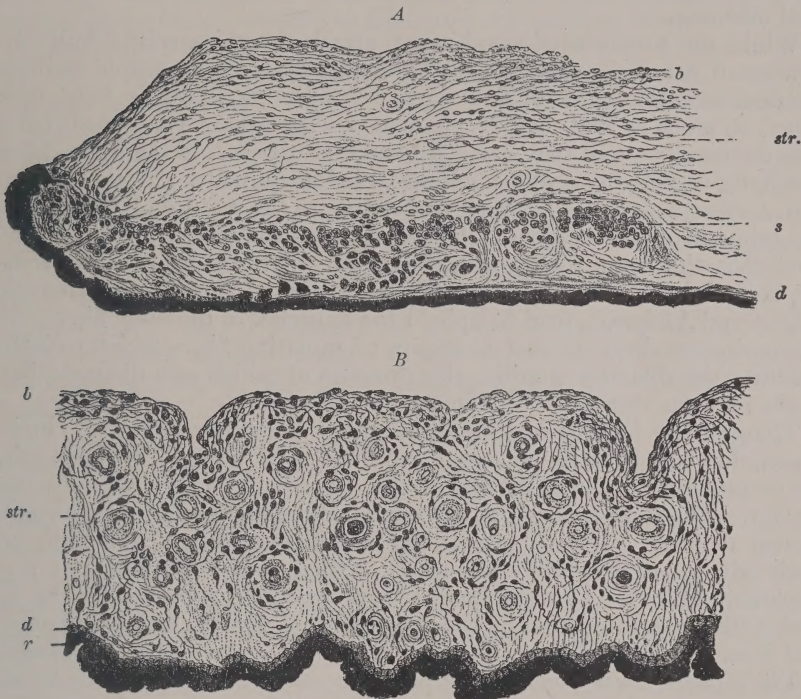


FIG. 32.—Sections of the human iris: *A*, radial section; *B*, section across the radii (Retzius): *b*, anterior condensed zone and endothelium; *str.*, stroma-layer; *s*, bundles of muscular fibers composing the sphincter pupillæ; *d*, muscle-cells constituting the dilatator pupillæ; *r*, pigment layer of iris belonging to retinal tract.

the groups of involuntary muscle-bundles which constitute the sphincter and dilatator pupillæ muscles. The radially disposed blood-vessels and nerve-trunks are invested by local condensations of the iridial stroma, the perivascular sheaths so formed representing the most robust portions of the stroma layer, the intervening areas being occupied by a comparatively loose connective-tissue reticulum.

The variable and often large amount of pigment contained within the stroma layer in dark irides occurs as irregular accumulations of pigment-cells, the anterior layer and the pupillary zone usually containing the greatest number of the colored elements. In very dark irides the distribution of the pigment is very general, all portions of the stroma layer being filled with the colored particles.

The muscular tissue within the iris occurs within the vascular stroma layer, and includes the well-marked circular fibers surrounding the inner margin of the iris and constituting the *sphincter pupillæ*, and the much less evident and often disputed radially disposed fibers which form the *dilatator pupillæ*.

The *sphincter pupillæ* consists of an annular band of involuntary muscle, varying in width between 0.7 and 1.0 mm., according to the condition of contraction, and from 0.07 to 0.10 mm. in thickness. The immediate edge of the pupil is not formed by the muscular tissue, since the pigmented retinal sheet intervenes. The muscle occupies the posterior plane of the stroma layer, behind the blood-vessels; the bundles composing its outer border are loosely disposed, certain fibers often assuming an arched course and fading away in radial offshoots.

While the presence of a sphincter muscle is universally admitted, the existence of a radially disposed *dilatator pupillæ* is by no means undisputed. The demonstration of a distinct layer of radiating fibers is very unsatisfactory, so much so that many competent observers have concluded that such fibers do not exist, and that a true dilatator is absent, although the presence of radially disposed delicate spindle-cells is indisputable. Without entering upon a *résumé* of the various views relating to the nature of these spindle-cells lying in close relation with the posterior limiting lamella, it may be stated that the most recent and trustworthy investigations, both from the morphological and the physiological standpoint, as those by Retzius and by Langley and Anderson, tend to uphold the existence of dilatator fibers—if not as a continuous sheet, at least as groups of radiating fibers which collectively constitute the dilatator pupillæ, the presence of which as a distinct dilatator muscle may be regarded as definitely established.

The *posterior limiting lamella* has likewise been the subject of much discussion, due largely to the uncertain relations of the layer of delicate spindle-cells occupying the iridial stroma in the immediate vicinity of the posterior pigment. The limiting lamella, or basal membrane, appears as a clear layer of great delicacy, its maximum thickness not exceeding 0.002 mm., which closely adheres to the deeply pigmented retinal zone, with which it is often inseparably united. The lamella in question may be regarded as the attenuated anterior continuation of the membrane of Bruch, which extends forward from the choroid over the orbiculus ciliaris and ciliary processes.

The *pigment layer* covering the posterior surface of the iris as far as the anterior margin of the pupil, although a conspicuous anatomical portion of the iris, morphologically represents the anterior segment of the atrophic portion of the nervous tunic—the *pars retinæ iridica*. The deeply colored layer, although ordinarily appearing as a uniform stratum of pigment-particles, in reality consists, as seen in suitable preparations, of two distinct layers—an outer, made up of low irregular fusiform elements, and an inner, composed of short polygonal cells; these layers are continuous as the anterior margin of the pupil and represent the double-layered anterior lip of the optic cup. On approaching the ciliary processes the amount of pigment gradually lessens, first in the inner layer, and subsequently likewise in the cells of the outer layer; finally, at the base of the ciliary elevations the outer layer alone contains pigment-particles. The inner cells are covered on their free surfaces by an extremely delicate cuticular membrane, the *limitans iridis*, which is probably the continuation of the cuticle investing the ciliary portion of the retinal sheet.

The *blood-vessels* of the iris include the arterial stems given off from the

anterior border of the *circulus arteriosus iridis major*, situated around the periphery of the iris, from which the radially disposed arterioles proceed through the stroma layer as far as the sphincter zone. At this point they freely join to form a second anastomotic circuit, the *circulus arteriosus iridis minor*, which surrounds the pupillary opening and gives off three sets of twigs—an internal, for the supply of the sphincter muscle, and anterior and posterior groups to the corresponding layers of the iris stroma.

The capillary networks derived from these sources join to form *venous radicles* which take a generally radial course, the veins uniting at acute angles to form the larger venous trunks which accompany those from the ciliary processes along the inner border of the ciliary muscle and terminate by joining the large *venæ vorticosæ*. The vessels of the iris are provided with perivascular lymph-sheaths within the thickened adventitious coat.

The *lymphatics* of the iris are represented by the interfascicular tissue-spaces which constitute an intercommunicating system of clefts within the stroma, and at the periphery communicate with the spaces within the ciliary body and with the spaces of Fontana.

The *nerves* of the iris are derived from the *orbiculus gangliosus*, which, as already noted, is formed within the accommodative muscle by the branches of the ciliary nerves. The trunks destined for the iris pursue a spiral course toward the periphery, and upon entering the stroma break up into branches which soon become reunited, after undergoing new combinations, to form plexuses within the stroma-layer.

The nerves of the iris possess three varieties of terminal fibers: 1, motor endings within the muscular tissue; 2, sensory endings within the superficial layers of the stroma; 3, vaso-motor endings within the walls of the arteries and capillaries.

The presence of ganglion nerve-cells within the iris is doubtful. At best, they occur as small, sparingly distributed elements, usually of irregular multipolar form, the nervous nature of which is not beyond dispute.

The Nervous Tunic.—The Retina.—Viewed in the light of the more modern conceptions, the nervous coat can no longer be regarded as of the same limited morphological value as the other tunics of the eyeball, but must be considered as a true nervous center, consisting of a peripherally situated portion of the nervous system, and not merely as a complex apparatus for the perception of light-stimulus.

The entire nervous tunic, as representing the structures derived from the optic vesicle, extends from the optic-nerve entrance to the anterior pupillary margin. The modifications which take place within this extensive tract suffice to differentiate two sharply-defined segments—the *posterior*, embracing the hindmost part of the tunic from the optic entrance to the *ora serrata*, and constituting the functioning *pars optica retinae*; and the *anterior*, which includes the atrophic segment covering the posterior surface of the ciliary body and the iris, and hence appropriately designated as the *pars ciliaris* and *pars iridica retinae*, respectively.

The visual portion of the nervous tunic, or *retina proper*, is closely applied to the choroid, and extends from the optic entrance over the posterior two-thirds of the eyeball, ending abruptly at the ciliary region in a sinuous border, the *ora serrata*, where it passes over into the greatly attenuated anterior non-visual segment of the coat.

The retina during life and in health is perfectly smooth and transparent, its blood-vessels alone being distinguishable: owing to this transparency of its inner division the dark color of the deeply pigmented outer retinal layer

becomes an important factor in absorbing reflected light-rays and thus preventing interference. During life the retina possesses a purplish-red tint, due to the presence of the so-called *visual purple* within certain of its elements. After death the retina soon becomes cloudy, later appearing as a thin gray veil. In thickness the retina decreases from about 0.4 mm. at the posterior pole to little over 0.2 mm. in the vicinity of the ora serrata.

On examining the eye-ground (see also page 184) a conspicuous circular whitish area marks the position of the optic-nerve entrance, lying a little to the nasal or inner side of the posterior pole of the eyeball. The *optic disk*, *optic papilla*, *optic entrance*, or *porus opticus*, is not quite circular, but is elliptical in form, its longest diameter being vertical and measuring about 1.7 mm. as against 1.5 mm. in the horizontal direction. The surface of the optic disk often presents a distinct funnel-like depression, the *physiological excavation*, which results from the mode of development; the excavation is usually eccentrically placed, being somewhat toward the nasal side, where the depression is steepest and occupied by the retinal vessels. Remains of the fetal hyaloid artery may be seen as a filament of connective tissue extending into the vitreous body from the optic disk. The white appearance of the area is due to the scleral connective tissue of the lamina cribrosa and the medullated nerve-fibers shining through the semi-transparent layer of axis-cylinders which occupy the disk.

Critically examined through the ophthalmoscope, the margin of the optic nerve appears as a faint reddish outline; next the nerve the optic disk presents a narrow white annular edge, the *scleral ring*, which is the edge of the aperture in the fibrous tunic; outside of the scleral border a second circle, often quite dark, and not infrequently broken, appears as an irregular pigmented zone, the *choroidal ring*, the presence of which is due to the deeply colored choroid. The optic entrance corresponds with the "blind spot," the explanation of which is found in the absence of the perceptive elements within this area.

The *macula lutea*, or *yellow spot*, is an area of slightly oval form distinguished by its peculiar reddish-brown tint, which is due to the presence of diffused pigment-particles. The macula corresponds closely with the axis of the eyeball, and lies about 4 mm. to the temporal side of the centre of the optic entrance and about 0.75 mm. below the horizontal meridian. The limits of the yellow spot are not sharply defined, since it blends into the surrounding retina, but its form, when accurately studied, is usually almost circular or but slightly elliptical, since the oval form frequently described depends, probably, more upon ophthalmoscopic appearances than upon anatomical arrangement. The greatest diameter of the yellow spot measures a little over 2 mm., and often does not quite correspond with the horizontal meridian.

About the center of the macular area a dark-brown, apparently deeply pigmented spot marks the position of the *fovea centralis*, a depression in which the retina becomes greatly thinned, and thus allows the deeply-tinted subjacent pigment to become exceptionally conspicuous. The fovea corresponds to the point of highest acuity of vision, and anatomically is distinguished by profound modifications in the arrangement of the histological elements of the retina.

The size of the fovea as usually given, between 0.2 and 0.4 mm., is too small, the recent investigations of Dimmer, Golding-Bird, and Schäfer indicating a diameter exceeding 1 mm., and, exceptionally, approximating nearly 2 mm. Owing to the absence of the rods within the fovea, and there-

fore, likewise, of the visual purple, this region possesses an inherently lighter tint than the surrounding retina, sometimes appearing as a faintly tinted spot when examined with the ophthalmoscope. The *foveal reflex* seen with the mirror is due to the direction and slope of the sides of the depression, the variations in these resulting in the differences observed in the ophthalmoscopic image (compare with page 188).

The retina morphologically consists of two distinct layers—an outer and inner lamella, which correspond to the external and the internal layers of the optic vesicle; the outer lamella is represented by the pigment layer, while the inner lamella includes the remaining retinal strata. The inner lamella may be further subdivided into the *neuro-epithelial* and the *cerebral* layers.

Sections of the nervous tunic, when perpendicular to the surface of the membrane, show numerous strata, the outermost of which is distinguished by its dark color, and constitutes the retinal pigment; the succeeding layers differ widely in the amount of protoplasmic elements which they contain, and hence vary in the intensity with which they stain, so that the retina presents lighter and darker strata when seen in usual carmine or hæmatoxylin preparations. The designation of the retinal layers (Fig. 33), as well as their morphological relations from without inward, is as follows:

Retinal Layers.

I. Outer layer of optic vesicle,	Pigment layer,	Pigment layer.
	Layer of rods and cones, Layer of bodies of visual cells or outer nuclear layer,	
II. Inner layer of optic vesicle,	External plexiform layer or outer reticular layer,	Neuro-epithelial layer.
	Layer of bipolar cells or inner nuclear layer,	
	Internal plexiform layer or inner reticular layer,	Cerebral layer.
	Layer of ganglion-cells,	
	Layer of nerve-fibers,	

The retina may be regarded as an isolated portion of the central nervous system immediately connected with a highly specialized perceptive sense-apparatus: as other parts of the nervous axis, so the retina is composed of two varieties of elements, the nervous and the sustentacular, the latter being represented by the modified neuroglial reticulum and columns, the fibers of Müller. The nervous elements constitute collectively the *ganglion retinae*, and represent the cortical cells of the brain. In principle, therefore, the retina consists of the percipient elements, closely applied to the pigment layer, the ganglion retinae and the ganglion-cells with their fibers, which establish communication with the brain-centers.

The Pigment Layer.—The conspicuous deeply-colored stratum of pigment-cells which forms the most external layer of the retina is the direct representative of the attenuated outer lamella of the optic vesicle. It is composed of hexagonal elements, about 0.015 mm. in diameter, although subject to marked individual variation, smaller cells often surrounding larger ones. Close examination of the pigment-cells in section shows that the colored particles do not invade the entire protoplasm, but that an outer zone, containing the nucleus, is clear, the pigment being confined to the middle and inner segments of the cells. The inner margin of the pigment-cells is irregular, in contrast to the smooth external border and in close relation to the outer ends of the rod and cone segments of the visual cells (Fig. 34).

The pigment-cells are profoundly affected by light stimulus, since under the influence of light the colored particles migrate toward the rods and cones, between which the protoplasm of the pigment-cells extends (Fig. 35). After

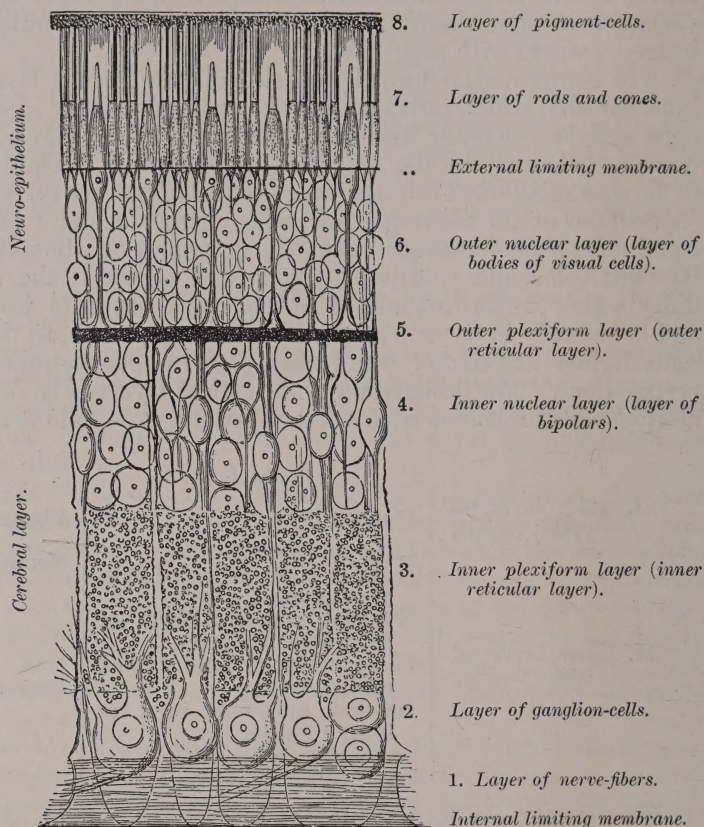


FIG. 33.—Diagrammatic section of the human retina (Max Schultze).

being subjected to darkness, on the contrary, the pigment particles are retracted and collected within the middle or so-called *basal zone* (Fig. 36). The relation between the pigment-cells and the rods and cones explains the variations in the

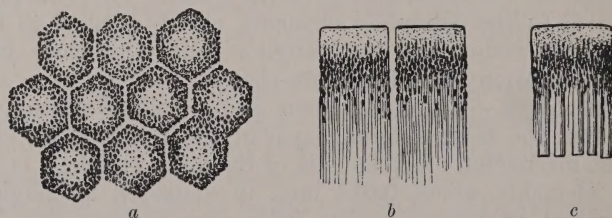


FIG. 34.—Pigmented epithelium from human retina (Max Schultze): a, surface view of cells, showing clear nuclei and intercellular lines; b, cells seen in profile, with protoplasm extended between percipient elements; c, cell still connected with rods.

degree of attachment between the colored and remaining portions of the retina: after exposure to light the intimate relation between the pigment and percipient elements renders the attachment between the two originally distinct lamellæ

much stronger than that existing after seclusion in darkness, under which conditions the tendency to the natural separation of the embryologically distinct lamellæ becomes pronounced, the pigment then remaining attached to the choroid when the retina is removed.

The Layer of Neuro-epithelium.—Under this heading are included two strata, which are usually described as the layer of rods and cones and the external nuclear layer, the former being the specialized outer parts, and the latter the extended and attenuated nucleated bodies of the visual cells.

The *layer of rods and cones* represents the highly differentiated outer extremities of two forms of light-perceptive elements, the *rod-* and the *cone-visual cell*. Under high amplification, as seen in section, *rods* of the human retina appear as elongated cylindrical forms, about 0.060 mm. in length and 0.002 mm. in thickness, each consisting of an *outer* and *inner segment* of about

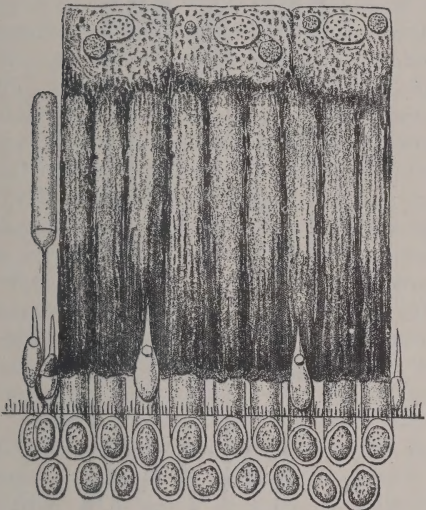


FIG. 35.—Section of frog's retina, showing the action of light upon the pigment-cells and upon the rods and cones (v. Genderen-Stort). The retina had been exposed to light for some time before killing; the pigment-cells have extended their protoplasm between the rods and cones nearly to their bases; the cones have retracted.

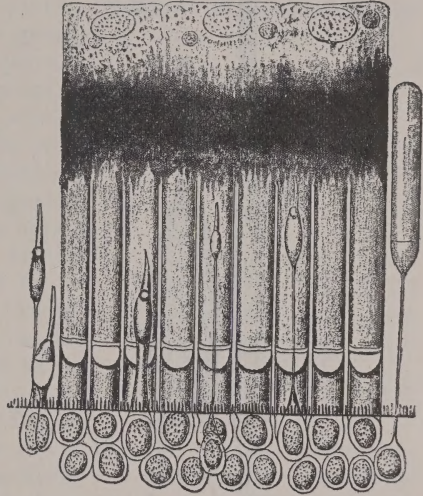


FIG. 36.—Section of frog's retina, showing action of darkness upon the pigment-cells and upon the rods and cones (v. Genderen-Stort). The retina had been kept in the dark for some hours before death, in consequence of which the pigment is retracted toward the nucleated part of the cells and from between the rods. The cones are elongated.

equal length. The *outer* segment possesses a uniform diameter and presents a homogeneous structure, being probably of the nature of a cuticular appendage. The external segments of the rods are of interest as being the chief, if not the sole, possessor of the visual purple or *rhodopsin*, the color being uniformly distributed throughout this part of the rod. The *inner* rod segment, with slightly increased diameter, is of feebly marked, ellipsoidal form, and exhibits more or less clearly a differentiation into an external faintly striated subdivision, the *rod-ellipsoid*, and an internal granular area, the *lenticular body* (Fig. 37).

The *body* of the rod-visual cell lies within the external nuclear zone and consists of the attenuated column of protoplasm, the *rod-fiber*, and the more conspicuous nucleus, the *rod-granule*. The rod-fiber is directly continuous with the inner part of the rod at the outer end, and extends into the external plexiform layer, within which it ends in a minute knob-like expansion in close relation with the terminal arborizations of the bipolar nerve-cells (Fig. 38).

The nuclei of the rod-cells, which usually present transverse dark and light stripes, are of much greater thickness than the rod-fiber, in consequence of which the position of the nucleus in each visual cell is indicated by a marked enlargement consisting of the nucleus surrounded by a thin envelope of protoplasm. The nuclei, or rod-granules, are situated at all layers, and contribute far the larger share of the deeply staining bodies which constitute the chief elements of the outer granule-layer.

The *cone-visual cells* are made up of the same general divisions as the associated rod-elements, including the specialized outer part, the cone, and

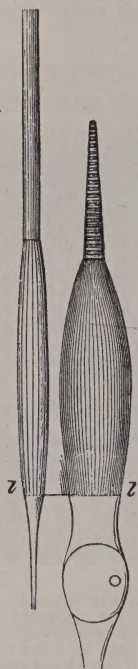


FIG. 37.—A rod and a cone from the human retina (Max Schultze). The line, *z, z*, indicates the position of the external limiting membrane; the portion of the figure unshaded represents parts of the visual cells contained within the outer nuclear layer.

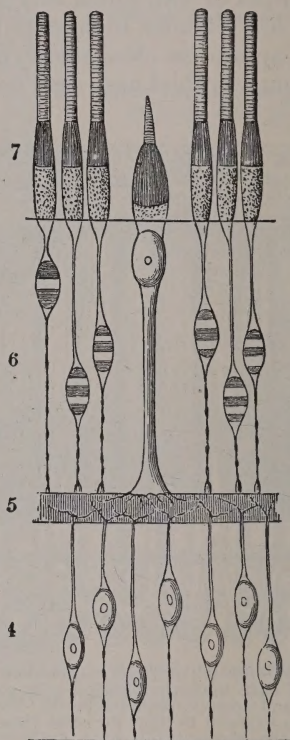


FIG. 38.—Diagram of the neuro-epithelial elements of the retina (Quain-Schwalbe): 4, bipolar nerve-cells, related to the rod- and cone-visual cells in the outer plexiform layer (5); 6, the nucleated bodies of the rod- and cone-visual cells, containing the rod- and cone-granules (nuclei) and the rod- and cone-fibers (these parts of the visual cells constitute the outer nuclear layer); 7, the layer of rods and cones which represents the outer highly specialized ends of the visual cells: each rod and cone is composed of the outer and inner segment.

the cone-cell body within the external nuclear layer. Each *cone* comprises an outer and an inner segment, which differ both in length and in thickness. In contrast to the almost uniform diameter and length of the two parts of the rods, the outer segment of the cones is shorter and thinner than the inner segment, which is conical, or, more accurately regarded, ellipsoidal, and measures about 0.006 mm. where it is broadest. The cones do not extend as far into the pigment layer as the rods, terminating as blunted cones at a point about opposite the middle of the outer segments of the adjacent rods. The cones do not contain the visual purple, but possess a somewhat higher refrac-

tive index than the rods. While the outer cone segment displays a tendency to break up into transverse disks, the inner segment exhibits a faint longitudinal striation.

The *body of the cone-visual cell* contributes to form the external nuclear layer, and consists of the attenuated cell-body, the *cone-fiber*, and broader conspicuous nucleus, the *cone-granule*. The latter, instead of occupying all levels of the nuclear layer, as do the nuclei of the rod-cells, are limited to the zone immediately below the external limiting membrane, being continuous with the bases of the inner cone-segments: additional characteristics of the cone-granules are their large size, lack of cross-stripes, and possession of nucleoli. The cone-fibers terminate within the outer plexiform layer in expanded bases or feet, which stand in close relation with the arborizations formed by the terminal expansions of the cone-bipolars.

The entire number of rods within the human retina has been estimated by Krause at 130,000,000; that of the cones, by Salzer at 3,360,000; the number of rods, therefore in the man is greatly in excess of the cones throughout most parts of the retina—in the fovea, however, the cones are alone present. The numerical proportion between the two varieties of percipient elements varies in different parts of the nervous tunic, as shown by the variation in the pattern seen on inspecting the surface of the retina where the cones appear as larger circles surrounded by areas of smaller rings; the cones are usually separated by an interval occupied by three or four rods. In the vicinity of the macula the cones increase so that only a single row of rods intervene, while in the fovea the cones alone are present (Fig. 39).

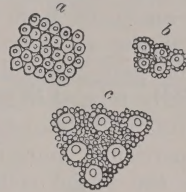


FIG. 39.—Surface view of the rods and cones, showing the relative distribution of these elements (Kölliker): *a*, from macula lutea, where only cones are present; *b*, from near macula, where only a single layer of rods separates the cones; *c*, from midway between macula and ora serrata, where rods preponderate.

The External Plexiform, or Outer Reticular

Layer.—This stratum lies next the layer of visual cells or neuro-epithelium, and is the first of the lamellæ which constitute the cerebral division of the retina. The layer appears as a light, faintly staining zone, about 0.01 mm. in breadth, the apparent granular structure of which, as seen under moderate amplification, giving place to an intricate reticulum when examined with higher magnification. The true nature of this reticulum was demonstrated only after the introduction of the more recent improved methods of staining by the Golgi silver and methylene-blue processes: recent investigations have shown that the major part of the plexiform layer consists of the delicate ramifications and intricate interlacings of the processes of the nerve-cells constituting the ganglion retinae and occupying the inner nuclear zone, held together by the delicate framework of sustentacular tissue.

The exact relations between the central extremities of the cone- and rod-visual cells and the endings of the nerve-cell processes have long been the subject of discussion. The direct connection formerly supposed to exist between the nerve-cells and the visual cells is no longer tenable in the light of our modern conceptions regarding the ultimate endings of nerve-processes, since the best authorities are agreed that each nerve-cell exists as an independent element, whose relation to other cells is one of contiguity and not of anatomical continuity. The nervous elements in close relation with the visual cells are the “rod” and “cone” bipolars, the nucleated bodies of which form the conspicuous “granules” of the inner nuclear layer. The peripherally directed processes of these nerve-cells extend within the external

plexiform layer and terminate in end-arborizations surrounding the inner extremities of the visual cells, which also penetrate into the reticular zone.

Additional nervous elements, the *horizontal*, *basal*, or *stellate cells*, are found within the external plexiform layer; they exist in two forms, the *smaller outer* and the *larger inner cells*. The former are flattened stellate elements which lie within the outer part of the plexiform layer, through which their long axis-cylinder processes extend for considerable distances to terminate in arborizations surrounding the ends of the visual cells, thus establishing indirect conduction between the elements lodged within the plexiform stratum. The larger inner horizontal cells occupy the deeper portions of the layer, some possessing descending processes which penetrate centrally as far as the inner plexiform layer, in which they terminate in arborizations.

The Layer of Bipolar Nerve-cells, or the Inner Nuclear Layer.—This stratum, as usually seen, closely resembles the outer nuclear layer, being apparently composed of large numbers of deeply staining granules. The layer measures from 0.035 mm. in the vicinity of the optic disk to 0.018 mm. at the ora serrata.

The ganglion-cells of the layer consist of two chief varieties—those especially related to the rod-visual cells, and hence appropriately called *rod-bipolars*; and those associated with the cone-cells, known as the *cone-bipolars*. The particular purpose of the bipolars is to supply the connecting link between the visual cells, around which they terminate on the one hand, and the large ganglion elements giving off the nerve-fibers to the brain, in relation to which their centrally directed processes expand, on the other. Reference to Fig. 40 shows that the arrangement of the processes of the cone-bipolars differs from that of the processes of the rod-bipolars: the latter extend through the entire thickness of the inner plexiform layer to the bodies of the ganglion-cells, which they enclose with their arborizations. The descending processes of the cone-bipolars, on the contrary, are limited to the inner plexiform layer, meeting with the expansions of the ascending dendrites of the large ganglion-cells at various levels, where the interlacing

FIG. 40.—Elements of the mammalian retina after treatment with the Golgi silver method (Cajal):

I. Section of the dog's retina: *a*, cone-fiber; *b*, rod-fiber and nucleus; *c*, *d*, bipolar cells (inner granules) with vertical ramification of outer processes destined to receive the enlarged ends of rod-fibers; *e*, bipolars with flattened ramification for ends of cone-fibers; *f*, giant bipolar with flattened ramification; *g*, cell sending a neuron or nerve-fiber process to the outer molecular layer; *h*, amacrine cell with diffuse arborization in inner molecular layer; *i*, nerve-fibrils passing to outer molecular layer; *j*, centrifugal fibers passing from nerve-fiber layer to inner molecular layer; *m*, nerve-fibril passing into inner molecular layer; *n*, ganglionic cells.

II. Horizontal or basal cells of the outer molecular layer of the dog's retina. A, small cell with dense arborization; B, large cell, lying in inner nuclear layer, but with its processes branching in the outer molecular; *a*, its horizontal neuron; C, medium-sized cell of the same character.

III. Cells from the retina of the ox: *a*, rod-bipolars with vertical arborization; *b*, *c*, *d*, *e*, cone-bipolars with horizontal ramification; *f*, *g*, bipolars with very extensive horizontal ramification of outer process; *h*, cells lying on the outer surface of the outer molecular layer, and ramifying within it; *i*, *j*, *m*, amacrine cells within the substance of the inner molecular layer.

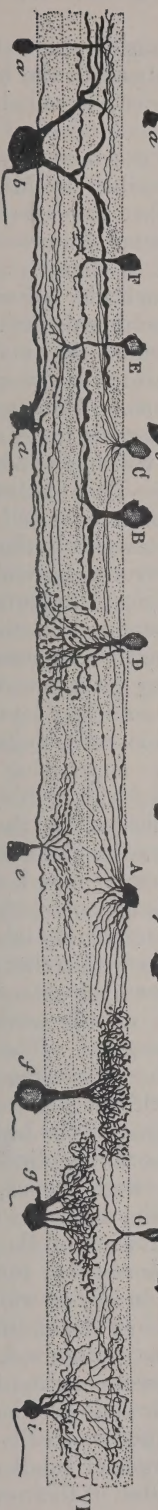
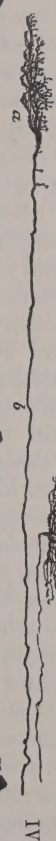
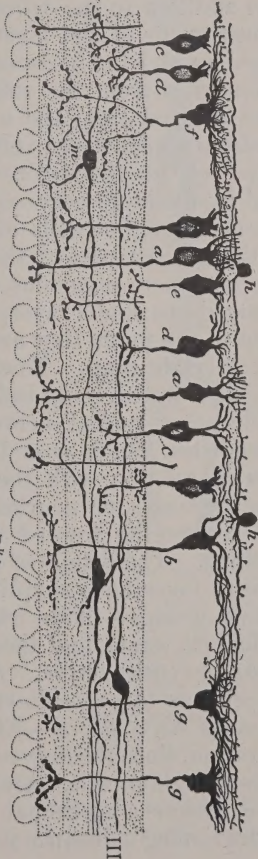
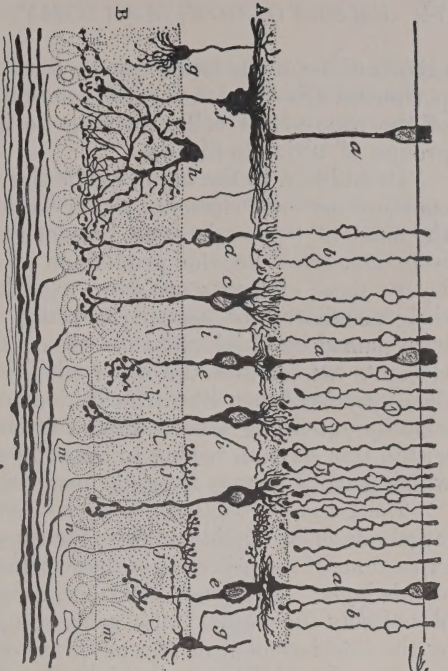
IV. Neurons or axis-cylinder processes belonging to horizontal cells of the outer molecular layer, one of them, *b*, ending in a close ramification at *a*.

V. Nervous elements connected with the inner molecular layer of the ox's retina: A, amacrine cell, with long processes ramifying in the outermost stratum; B, large amacrine with thick processes ramifying in second stratum; C, flattened amacrine with long and fine processes ramifying mainly in the first and fifth strata; D, amacrine with radiating tuft of fibrils destined for third stratum; E, large amacrine, with processes ramifying in fifth stratum; F, small amacrine, branching in second stratum; G, H, other amacrones destined for fourth stratum; *a*, small ganglion-cell sending its processes to fourth stratum; *b*, a small ganglion-cell with ramifications in three strata; *c*, a small cell ramifying ultimately in first stratum; *d*, a medium-sized ganglion-cell ramifying in fourth stratum; *e*, giant cell, branching in third stratum; *f*, a bistratified cell ramifying in second and fourth strata.

VI. Amacrones and ganglion-cells from the dog: A, amacrine with radiating tuft; B, large amacrine passing to third stratum; C and G, small amacrones with radiations in second stratum; F, small amacrine passing to third stratum; D, amacrine with diffuse arborization; E, amacrine belonging to fourth stratum; *a*, *d*, *e*, *g*, small ganglion-cells, ramifying in various strata; *b*, *f*, large ganglion-cells, showing two different characters of arborization; *i*, bistratified cell.

VII. Amacrones and ganglion-cells from the dog: A, B, C, small amacrones ramifying in middle of molecular layer; *b*, *d*, *g*, *h*, *i*, small ganglion-cells showing various kinds of arborization; *f*, a larger cell, similar in character to *g*, but with longer branch; *a*, *c*, *e*, giant cells with thick branches ramifying in the first, second, and third layers; L, L, ends of bipolars branching over ganglion-cells.

I.



VII.

VI.

V.

IV.

III.

II.

arborizations of the two elements form plexuses of considerable extent. The peripheral arborizations of the cone-bipolars expand beneath the broad bases of the cone-visual cells, forming horizontally-extended, terminal plate-like groups of ultimate fibrillæ.

In addition to the bipolar cells the inner zone of the inner nuclear layer contains nervous elements which were long ago described by Müller under the name of "spongioblasts," under the impression that the cells in question were concerned in the production of the sustentacular framework of the layer: these elements are now regarded as nervous in character, and, from their peculiarity of seemingly being without axis-cylinder processes, have been named by Cajal *amacrine cells*. The richly branching dendrites of these elements extend into the inner plexiform layer, in which they end either in the expanded brush-like arborizations of the *diffuse amacrine*s, or in the horizontally extending arborizations of the *stratiform* type. A few oval nuclei within this stratum belong to the long columnar supporting fibers of Müller, which usually possess irregular nucleated expansions within the zone.

The Internal Plexiform, or Inner Reticular Layer.—This has been already largely described incidentally to the consideration of the bipolar cells, since the expansions of the processes of these elements contribute largely to the formation of this layer. The inner plexiform stratum, about 0.04 mm. in width, resembles closely the similar outer zone, being really an intricate reticulum formed by the interlacement of the processes of nerve-cells situated in the adjacent laminae. In addition to the delicate supporting framework of neuroglia, the principal constituents of the layer are the descending processes of the rod- and cone-bipolars and the horizontal cells of the inner nuclear layer, and the ascending dendrites from the subjacent large ganglion-cells, augmented by the processes derived from the amacrine cells. The supporting fibers of Müller are also conspicuous as vertically coursing striæ within this stratum.

The Layer of Ganglion-cells.—This layer, as indicated by the name, is characterized by the large nervous elements which form its chief constituent. The conspicuous ganglion-cells are disposed as a closely-placed single row throughout the greater part of the retina: toward the macular region, however, they become more numerous, and in the immediate vicinity of the yellow spot are arranged as a double layer, increasing in number within that area until, at the margin of the fovea, they are superimposed to such an extent that they lie from six to eight deep. Toward the ora serrata, on the contrary, they are sparingly distributed, lying isolated and widely separated. The ganglion-cells resemble other typical nervous elements in the possession of richly branched dendrites, which pass into the inner plexiform layer to end in arborizations in relation with the descending processes of the bipolars, and axis-cylinder processes, or neurites, which become the axis-cylinders of the nerve-fibers converging toward the optic entrance, and thence, as optic fibers, brainward. The details of the distribution of the dendrites within the inner plexiform layer have supplied a basis for the division of the ganglion-cells into two groups—those which terminate in *horizontal* ramifications limited to definite strata, and those which terminate in *diffuse* ramifications distributed to the entire layer. Additional distinctions, depending on the size of the cells, as *large*, *medium*, and *small*, are also recognized.

The Layer of Nerve-fibers.—This is largely the direct contribution of the preceding stratum, since the nerve-fibers composing this zone are the extended neurites of the ganglion-cells. After arising from the presiding cells the fibers almost at once assume a horizontal course and form larger or smaller bundles, which, after traversing a distance varying with the position of their origin, con-

verge to the optic entrance and contribute to the formation of the visual nerve. The size of the nerve-fibers is generally small, but a limited number of very large fibers also exist: these, it is supposed, are connected with ganglion-cells of exceptional magnitude.

In addition to the centrally coursing fibers the presence of fine peripherally directed, or "centrifugal," nerve-fibers has been established. The central connections of such fibers are at present uncertain; their peripheral terminations lie within the inner plexiform layer, and apparently have no discoverable connection with the cells of the ganglion layer.

The bundles of nerve-fibers, while pursuing a general radial course toward the optic entrance, freely intermingle and form a reticulum. The presence of the macula lutea disturbs the strictly radial course of the bundles on the temporal side of the optic disk, the space separating the latter from the yellow spot being traversed by from twenty-five to thirty delicate fasciculi which possess an almost straight course from the macula to the disk; these fibers collectively constitute the *macular bundle* described by Michel. The bundles adjacent to the macular group suffer deflection from the typical radial course and arch above and below the macular area; beyond the yellow spot the arching bundles possess the typical radial arrangement.

The Sustentacular Tissue.—The *sustentacular tissue*, or *neuroglia*, of the retina exists in two forms—as the conspicuous radial fibers of Müller and as the spider-cells (Fig. 41).

The *fibers of Müller* constitute a sustaining framework which supports the nervous elements as well as the neuro-epithelium, coming into intimate relations with all parts of the retina. The Müllerian fibers are modified neuroglia-cells, derived originally from the ectodermal tissue of the wall of the neural tube, which extend through almost the entire thickness of the retina, reaching from the rods and cones, between which they contribute delicate septa, to the inner surface of the nervous tunic, where their expanded bases unite to form a seemingly continuous sheet, the *membrana limitans interna*. The fibers are slender nucleated columns which contribute lateral offshoots at various levels to the several retinal layers, among the elements of which the processes break up into delicate sustaining fibrillæ and reticula. The broadest expansion along the course of the fibers usually occupies the inner nuclear layer, and also contains the oval nucleus. At a level corresponding to the position of the inner ends of the rods and cones the sustentacular fibers come into apposition and form an apparent fenestrated partition, the *membrana limitans externa*, from the outer surface of which minute septa project between the rods and cones,



FIG. 41.—A supporting fiber of Müller after staining by Golgi's silver method (Ramon y Cajal). The extensions of a single fiber are shown in relation to the several retinal layers: 1, layer of nerve-fibers; 2, ganglion-cells; 3, inner plexiform layer; 4, inner nuclear layer; 5, outer plexiform layer; 6, outer nuclear layer; *m.l.e.*, *m.l.i.*, respectively, the external and internal limiting membrane; *b*, nucleus of fiber; *a*, process extending into internal plexiform layer.

probably acting as an insulation of the individual percipient elements. As already noted, the inner ends of the fibers of Müller are greatly enlarged, the *bases* of the conspicuous pyramidal or conical expansions coming into close contact and producing the appearance, when treated with silver nitrate, of a continuous layer of endothelial plates; the bundles of retinal nerve-fibers pass between the diverging fibers to continue their radial course. Within the fiber layer additional sustentacular elements exist as the *spider-cells*, neuroglial elements whose characteristic appearance is due to the long, delicate processes which extend from the cell-body between the nerve-fibers in various directions.

The Macula Lutea.—The structure of the retina undergoes important modifications within two areas—at the macula lutea and the ora serrata (Fig. 42). On approaching the macula the ganglion-cells become so numerous that a single layer no longer suffices for their accommodation, and consequently they lie two deep; within the macular area the number further increases, so that they constitute a stratum which includes from six to eight rows of the nervous elements. On reaching the fovea centralis, however, the greatly thickened ganglion-layer rapidly decreases in thickness toward the center of the depression, becoming scattered and no longer sufficient to constitute a complete stratum, until at the bottom of the pit the ganglion-cells are altogether absent. The fiber-layer consequently suffers a corresponding diminution, and disappears as a distinct stratum at the point where the ganglion-cells end. The bipolar cells continue to the center of the fovea as an irregular row of small elements supported within the finely reticular tissue which represents the fused outer and inner plexiform layers, and fills the space between the visual cells and the inner surface of the retina.

The most prominent stratum within the fovea is that formed by the visual cells, here composed entirely of the cone-cells, which present a depth about three times that of all the more internally placed strata combined. The cones gradually lengthen on approaching the foveal center until, over the middle of the depression, they measure more than double the length of the corresponding elements at the margins of the pit: associated with the increased length, the cones become greatly attenuated, appearing as long, delicate, slender fibers of which the outer segment contributes by far the greater part (Fig. 42).

The external limiting membrane exhibits a slight inward deflection over the area included within the outward curve of the inner membrane: this outer depression, the so-called *fovea externa*, produces, however, but slight dipping inward of the outer surface of the retina, as the increased length of the cones in a measure compensates for the sinking of the limiting membrane. It is probable that the position of the external fovea corresponds to an associated thickening of the choroidal tissue. In recapitulation, therefore, the layers occupying the center of the fovea are the cone visual cells, constituting the layer of cones and the external nuclear layer and the fused outer and inner plexiform strata, with the included bipolar cells. The ganglion-cells and their derivative nerve-fibers are absent in the center of the fovea.

The Ora Serrata.—The extreme anterior limit of the visual portion of the retina is distinguished by a sudden diminution in the thickness of the nervous tunic, dependent upon the abrupt termination of the percipient elements, as well as those layers concerned in the transmission of the light stimuli centrally, the layer of retinal pigment alone retaining its identity in the further extension of the nervous coat.

The characteristic series of about forty well-marked dentations observed

in the adult retina are closely associated with the accommodative function, since in early life, before accommodation is fully exercised, the typical serrated border is wanting, the termination of the visual part of the retinal sheet being marked by a comparatively smooth line, the "transition border" of Schön, beset with numerous minute projections which afford attachment to certain of the delicate zonular fibers.

The sudden reduction of the retina depends especially upon the disappearance of the plexiform strata, the layer of rods and cones, however, having previously lost its integrity as a distinct zone. The inner nuclear layer is continued farthest, at the anterior limit of the ora passing into the single layer of columnar elements, which, in conjunction with the pigmented cells, are continued over the ciliary zone and processes as the *pars ciliaris retinae*.

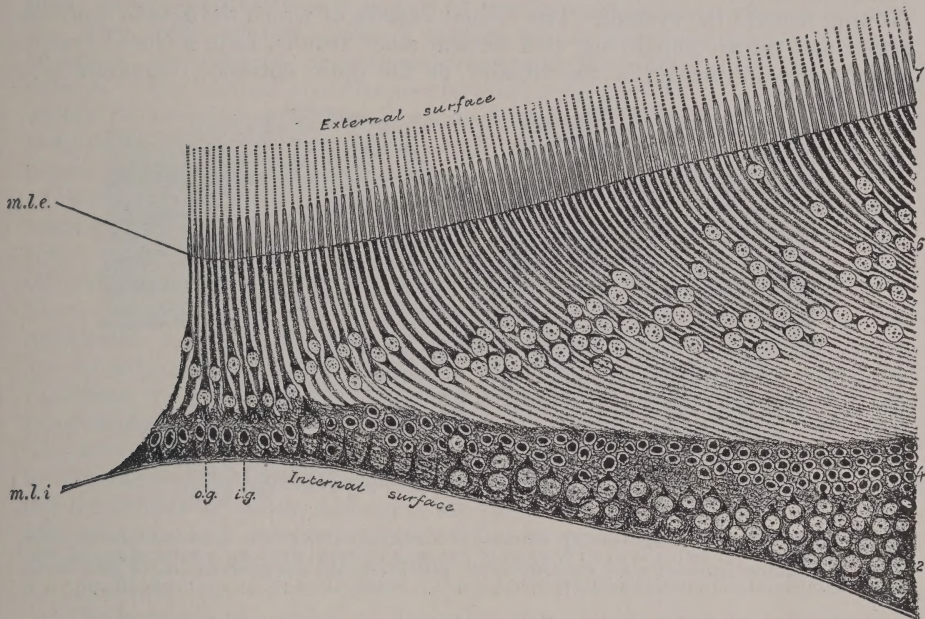


FIG. 42.—Diagrammatic section through the fovea centralis of the human retina (Golding-Bird and Schäfer): 2, ganglion-cell layer; 4, inner nuclear layer; 6, outer nuclear layer, the cone-fibers forming the so-called external fibrous layer of Henle; 7, cones; *m.l.e.*, external limiting membrane; *m.l.i.*, internal limiting membrane; *o.g.*, *i.g.*, outer and inner granules (cone-nuclei and bipolars).

The radial fibers of Müller are especially well developed in the vicinity of the ora serrata, being of large size and numerous. So close is the relation between the sustentacular tissue and the ora that it has been suggested that the supporting fibers are continued beyond the limits of the serrated border and become connected with the zonular fibers.

The Optic Entrance.—The point toward which the centrally directed axis-cylinders of the fiber-layer converge to escape from the interior of the eyeball and to form the optic nerve is marked by a light-colored circular area, varying from 1.5 to 1.7 mm. in diameter, the *optic entrance*, *optic disk*, or *optic papilla*. The surface of the yellowish- or bluish-white disk is broken by the central retinal vessels which pierce the area eccentrically, lying usually somewhat nearer the nasal side, and pass over the margins of the disk to gain the surrounding fiber-layer.

On examining a vertical section through the optic entrance (Fig. 43) it

will be seen that the thick bundles of the optic fibers which arch over the margins of the interrupted retinal and choroidal layers to gain the disk produce a slight elevation, the *papilla optici*: in consequence of the rapid arching of the fibers the center of the disk is lower than the margin; hence the production of the so-called *physiological excavation* (see also page 66). The remaining retinal layers terminate abruptly in the vicinity of the nerve-entrance, a narrow maze of reticulated *intermediate tissue* separating them from the arched bundles of nerve-fibers. The ganglion-cells are the first to disappear, while the visual cells continue farthest toward the nerve, the rod- and cone-fibers assuming an oblique position.

The *blood-vessels* of the retina first appear on the optic disk as they emerge from the bundles of nerve-fibers, between and parallel to which they run from the point at which they obliquely enter the optic nerve some 15 to 20 mm. beyond the eyeball. The retinal vessels, of which the *arteria centralis retinae* and the accompanying vein are the chief trunks, form a closed system which only indirectly, in the vicinity of the optic entrance, communicates

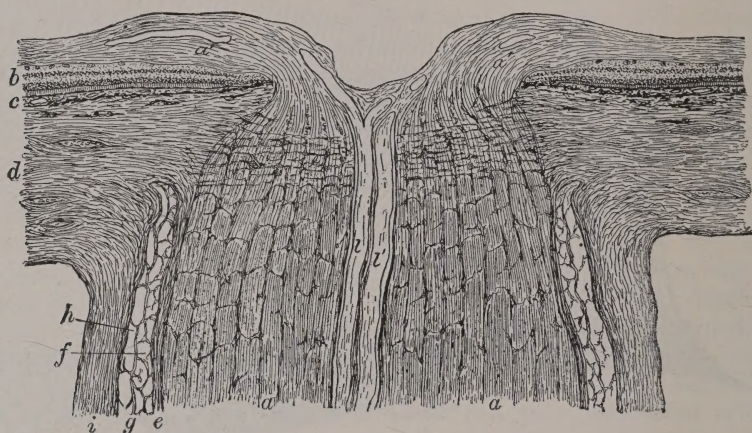


FIG. 43.—Longitudinal section of optic entrance of human eye (Piersol): *a, a*, bundles of optic fibers, which spread out over retina at *a', a'*; *b, b*, layers of retina; *c*, choroid; *d*, sclera, continued across optic nerve as the lamina cribrosa; *e, g, i*, respectively the pial, arachnoid, and dural sheaths of optic nerve, enclosing subdural and subarachnoid lymph-spaces; *l, l'*, retinal blood-vessels cut longitudinally.

with the vessels distributed to the remaining coats of the eyeball. On attaining the optic disk the central artery divides into two main stems, the *superior* and *inferior pupillary branches*, directed almost vertically upward and downward. These subdivide into smaller branches, the *superior* and *inferior nasal* and *temporal arteries*, which run mesially and laterally; additional twigs pass directly outward as the *superior* and *inferior macular arteries* to supply the important area of the yellow spot. While the greater part of the macular area is richly supplied with blood-vessels, the fovea centralis is without them.

On examining the details of the vascular distribution of the retina it is found that the vessels of larger size are contained within the fiber-layer, dividing into branches which do not anastomose, being "end-arteries." The arterioles break up into rich capillary networks, which are distributed as the *inner* and *outer plexuses*, the former lying at the junction of the fiber- and the ganglion-layer, while the latter is situated within the inner nuclear zone, being especially destined for the nutrition of the functionally active bipolar nerve-cells. As already noted, the nutrition of the perceptive elements, the visual cells, is mainly maintained by the dense vascular network of the chorio-capillaris of the middle tunic.

The *lymphatics* of the retina are represented chiefly by the perivascular lymph-channels which enclose all the veins and capillary blood-vessels, and communicate with the subpial lymph-space of the optic nerve. Between the larger nerve-bundles, in the vicinity of the optic papilla, the interfascicular lymph-clefts may be regarded as additional lymphatic channels. The fact that injections from the subpial space pass between the pigment layer and the rods and cones, and again between the inner surface of the retina and the adjacent hyaloid membrane, has been regarded as proof of the existence of lymph-spaces in these situations.

The Optic Nerve.—The nerve of sight, about 5 cm. in length, is divisible into three segments—the *intracranial*, the *intraorbital*, and the *intraocular*. The first of these, the intracranial, extends from the optic commissure to the optic foramen, a distance of about 1 cm., and contains the extensions of the fibers which eventually pass to end in terminal arborizations associated with the nerve-cells of the cerebral centers within the pulvinar of the optic thalamus, the external geniculate bodies, and the anterior corpora quadrigemina. The cortical areas connected with sight have been definitely located within the occipital lobe, and probably include the cuneus. The intraorbital portion of the nerve presents a series of slight curves which render the nerve sigmoid rather than straight.

Transverse sections of the optic nerve show it to be composed of a large number, about eight hundred, of distinct bundles of medullated fibers separated from one another by connective-tissue septa, which are derived as offshoots from the pial sheath investing the nerve. The entire number of fibers contained within the optic nerve probably approaches a million, the measurable fibers having been estimated at about half that number by Salzer. In its arrangement and composition the optic nerve resembles a gigantic funiculus, the endoneurium being in the present instance represented by the penetrating pial tissue, while the sheath itself corresponds to the perineurium. The nerve-fibers vary in diameter from a delicacy which defies measurement to a thickness of 0.01 mm. In addition to the connective-tissue fibers forming the coarser trabecula and septa, the sustentacular tissue proper consists of neuroglia in which numerous spider-cells are prominent: these elements are supplemented by the deeply-staining connective-tissue cells belonging to the fibrous septa.

The intraorbital portion of the optic nerve is invested by extensions of the brain-membranes which form the corresponding *dural*, *arachnoidal*, and *pial sheaths*. The general character of these envelopes is similar to that of the meninges, the tough dural sheath lying outside and the pial sheath closely applied to the nerve, with the arachnoidal sheath between. Between the dural and arachnoidal envelopes lies the *subdural* lymph-space; between the arachnoidal and the pial sheaths, the *subarachnoidal* space. On reaching the fibrous tunic of the eyeball all these sheaths, together with the included spaces, terminate by blending with the fibro-elastic stroma of the sclera, the lymph-spaces extending sometimes for a short distance between the fibrous bundles of the outer tunic.

The external limit of the intraocular segment of the optic nerve is distinguished by the position at which the nerve-fibers acquire a medullary sheath on emerging from the sclerotic tissue which they traverse. The scleral bundles separate to allow the passage of the groups of optic fibers, and interlace with one another to form a sieve-like structure, the *lamina cribrosa* (Fig. 43). The bridging fibers are contributed particularly by the inner third of the scleral coat, but are supported by additional bundles

of fibrous tissue derived from the connective-tissue septa of the optic nerve.

The Crystalline Lens.—The most important part of the refractive apparatus of the eye consists of a transparent lenticular body, the *crystalline lens*, of circular outline and biconvex section, which supports the pupillary margin of the iris in front and rests within a depression, the *patellar fossa*, on the anterior surface of the vitreous body behind; laterally, the lens is connected with the supporting fibers which collectively form the suspensory ligament, or zone of Zinn. The lens substance consists of a soft, compressible material of such transparency during youth as to possess no color; later, with the advent of senile changes, it assumes a yellowish tint and slight opalescence, which first affects the central portion of the lens and gradually extends toward the periphery. Early in life the lens substance is of the same consistency throughout; gradually, however, the central portion becomes harder, until in advanced age considerable difference in condensation distinguishes the "nucleus" from the cortical layers. The lens being non-vascular, its nutrition is maintained entirely by the intercellular transmission of nutritive fluids: the differentiation of the central and peripheral portions is due to the loss of water of the favorably situated central portion of the lens. The hardening which thus gradually takes place results in loss of elasticity of the lens substance, which change is manifested in the defective accommodation which characterizes the eyes of persons after middle life. Owing to the increased density of the nucleus, the central portion of the lens of advanced years reflects more light, and the pupil consequently lacks the jet black of young eyes and appears slightly dimmed.

The soft lens substance is enclosed within a delicate elastic but strong membrane, the *lens capsule*: the latter is resistant to reagents, such as alcohol and acids, as well as to putrefactive changes. While possessed of considerable strength, it is brittle and readily torn by sharp instruments; when incised its cut edges roll in a characteristic manner, with the outer surface inward. When viewed in section that portion of the enveloping membrane covering the front surface of the lens is seen to be distinctly thicker than the corresponding part behind: these differences have given rise to the designation of these portions of the membrane as the *anterior* and *posterior* capsule, although both are but parts of the same general envelope.

Invested by its capsule, the lens measures from 9–10 mm. in its transverse diameter, being larger in old and large subjects; its average thickness is about 4 mm., but this dimension necessarily varies with the condition of accommodation, being somewhat greater when the eye is fixed on near objects and less when accommodated for distance. The radius of curvature of the surfaces also varies under such changing conditions, that of the anterior surface, however, manifesting greater change under the extremes of accommodation than that of the posterior; thus, while the radii of the anterior surface for distant and near vision are respectively 10 and 6 mm., those of the posterior surface for the same conditions are respectively 6 and 5 mm. These figures establish the fact that the curvature of the anterior surface of the lens is much more affected in accommodation than that of the posterior, which remains almost unchanged. (See also page 135.) The length of a meridian of the lens measures about 12 mm. The average weight of the lens is about 0.22 gm., and the specific gravity 1.121. The anterior pole of the lens lies about 2.3 mm. behind the cornea under passive conditions of accommodation; its posterior pole, about 15.5 mm., in front of the macula lutea. Critical examination has demonstrated a slight outward devi-

ation, of from three to seven degrees, of the antero-posterior lens-axis from that of the eye; an additional, but smaller, vertical deviation has also been noted.

The structure of the crystalline lens can best be appreciated after recalling what has already been stated in connection with its mode of formation. The lens develops by the elongation and modification of the original ectodermic epithelial cells, which become converted into the lens-fibers, those constituting the posterior wall of the primary lens-sac at first composing the entire lens substance. Subsequently additional layers of lens-fibers are produced by the elongation and specialization of the cells constituting the anterior wall of the lens-sac, which later are known as the *epithelium of the anterior capsule*. The region in which the transformation of the epithelial cells into lens-fibers takes place corresponds to the equatorial area, and is known as the *transitional zone*; throughout the entire period of growth this region exhibits the conversion of the columnar epithelial elements of the anterior capsule into the elongated meridionally arranged lens-fibers. The lens substance, therefore, is composed of modified epithelial tissue.

The capsule of the lens is of entirely different origin, since its development is due to mesodermic tissues, and is distinct from that of the lens substance.

The *capsule* of the lens envelops the lens substance on all sides with a delicate, highly elastic membrane, which, in addition to supporting the soft material constituting the bulk of the lens, affords attachment for the fibers of the suspensory ligament. The capsule varies in thickness, being most robust in the central area of its anterior surface, where it measures from 0.010 to 0.015 mm. in thickness, and thinner at the periphery; its most attenuated part is the central area of its posterior portion, where it measures from 0.005 to 0.007 mm. The capsule does not exhibit any details of structure, and in chemical composition and reactions differs from both fibrous and elastic tissue.

The *epithelium of the lens-capsule* lies beneath the anterior capsule alone, consisting of a single layer of polyhedral flattened cells, about 0.020 mm. in diameter. These elements morphologically represent the anterior wall of the original lens-sac. On approaching the margin of the lens the cells of the anterior capsule become more elongated, until finally, in the transition zone, the epithelial elements become converted into the young lens-fibers. As a result of these changes being confined to a limited area, the nuclear zone, a peculiar spiral figure, is produced by the elongating cells and their nuclei, to which the term *lens-whorl* has been applied.

The *substance* of the lens, constituting its entire bulk, is composed of layers of elongated and modified epithelial cells, the *lens-fibers*, united by an extremely thin layer of cement substance. The individual lens-fibers, as

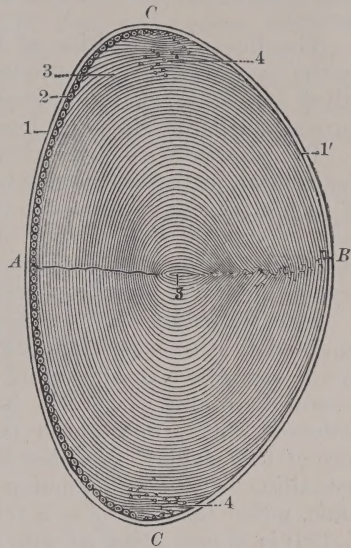


FIG. 44.—Meridional section through human crystalline lens (Babuchin): 4, anterior; B, posterior surface; C, C, equatorial region; 1, 1', anterior and posterior capsule; 2, epithelium beneath anterior lens-capsule; 3, lens substance composed of fibers; 4, transition zone where cells of anterior epithelium are converted into lens-fibers; 5, nucleus.

seen after isolation by boiling, maceration in dilute acids, and other methods, are long, ribbon-like fibers which, on transverse view, present a compressed hexagonal outline. The lens-fibers vary in length, those forming the outer layers of the lens being distinctly longer than those found within the nucleus: the former extend about two-thirds of the meridional distance from pole to pole, while the latter correspond to the length of the lens-axis. Additional differences in the breadth and thickness exist between the fibers from the periphery and central layers, the dimensions of the more superficially situated fibers being the greater. The fibers also exhibit variations in consistency, depending upon the relatively greater amount of tissue-juices in the cortical layers.

The lines of apposition of the meridionally arranged lens-fibers, joined by the cement substance, produce definite figures of a stellate form, the so-called *lens-stars*, which are especially well marked in the young or in the cortical portion of the older lens. (See page 23.)

The growth of the lens after its primary development is due entirely to the addition of layers of new lens-fibers derived exclusively from the cells of the anterior epithelium, the transformation being limited to the equatorial zone. There is no evidence of the direct multiplication of the lens-fibers themselves, since these elements represent cells which have become specialized beyond the limits of reproduction.

The Vitreous Body.—The extensive space bounded by the crystalline lens and its suspensory ligament in front, and by the retina behind, is filled by the vitreous body or *humor vitreus*. The fresh vitreous body appears as a semi-fluid mass, perfectly transparent, whose general form resembles a flattened sphere, the anterior pole of which is further modified by the presence of the patellar fossa for the reception of the posterior surface of the crystalline lens. The function of the vitreous is to support the nervous tunic, rather than to act as a refractive medium, since its index of refraction (1.336) is almost identical with that of the aqueous humor, and but slightly in excess of that of water.

When the fresh vitreous is thrown upon a filter, by far the greater part of the tissue passes through as a watery fluid, a very slight proportion of the entire structure remaining as morphological constituents: this observation establishes the fact that the vitreous body anatomically consists of two portions, the supporting framework and the fluid tissue. Chemically, the vitreous consists of about 98.5 per cent. water, the remaining small proportion of the whole, composed of solids, includes salts, extractives, and minute quantities of proteids and nucleo-albumin.

The semi-fluid, gelatinous vitreous substance proper is enclosed within a delicate envelope, the *hyaloid membrane*, from which a delicate supporting reticulum extends throughout the mass of the vitreous body. Without considering in detail the conflicting views as to the structure of the vitreous body which from time to time have been advanced, it may be regarded as established that the vitreous substance represents an embryonal form of connective tissue modified by an unusual infiltration of water, so that its original condition as a connective tissue becomes masked.

The true nature of the tissue in question can only be determined by examination of the fetal vitreous before the infiltration of the watery constituents has taken place. The young tissue presents a delicate reticulation of connective-tissue elements, the interlacing fibrillæ forming a delicate meshwork containing numerous nucleated areas. With the advance of development the connective-tissue elements of the vitreous tissue become

less and less conspicuous, until the adult tissue contains only suggestions of the stellate cells which at one time were prominent morphological elements. In suitably prepared specimens a delicate supporting framework composed of exceedingly fine fibrillæ can be demonstrated in all parts of the vitreous: at the peripheral parts of the vitreous local condensations exist which in places, as within the patellar fossa, suffice to form the external limiting envelope. Membranous septa, concentrically or otherwise disposed, as described by various authors, must be regarded as artificial products if at all present.

The cellular elements of the adult vitreous (Fig. 45) are very meager, and consist in a few sparingly distributed atrophic connective-tissue cells; in addition to these elements, which belong to the vitreous tissue, *migratory leukocytes*, or *wandering cells*, also occur, especially immediately beneath the hyaloid membrane, where they all constitute the *subhyaloid cells*. These cells are derived probably from the blood-vessels in the vicinity of the optic entrance and the ora serrata.

The central portion of the vitreous is penetrated by a channel, the *hyaloid canal*, *canal of Stilling*, *canal of Cloquet*, or *central canal*, which extends

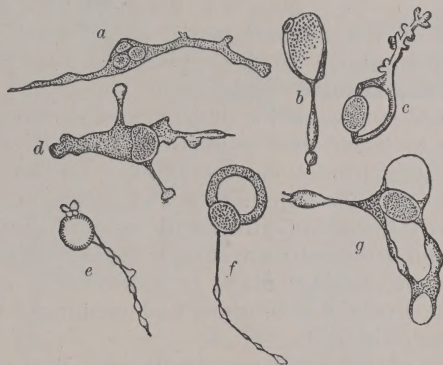


Fig. 45.—Morphological elements found within the vitreous body (Schwalbe): *a, g, d*, cells without vacuoles; *b, c, e, f, g*, vacuolated forms.

from the optic entrance toward the lens as far as the patellar fossa: this canal surrounds the atrophic remains of the fetal hyaloid vessels, which traversed the vitreous and supplied the vascular lens envelope. The channel begins as a slight enlargement, the *area Martegiani*, of a diameter equal to that of the optic disk, and ends in the neighborhood of the posterior lens surface in a blind, not infrequently somewhat dilated, extremity.

The *hyaloid membrane* encloses the greater part of the vitreous body as a transparent envelope of great delicacy which closely adheres to the retina. In eyes which have been kept for several days in dilute alcohol the hyaloid membrane can be demonstrated on the vitreous body, since in such specimens it can be separated from the retina without mutilation. The hyaloid membrane is wanting over that part of the vitreous body which surrounds the patellar fossa: within this depression the peripheral condensation of the supporting tissue of the vitreous body alone constitutes the limiting envelope of the soft gelatinous tissue within.

The Suspensory Apparatus of the Lens.—The position of the crystalline lens is maintained by means of a series of delicate bands, which pass from the vicinity of the ora serrata over the ciliary processes to be attached

to the periphery of the lens. These fibers collectively constitute the *suspensory ligament*, or *zone of Zinn*, a structure of great importance not only for the support of the lens, but also in effecting the changes in the curvature of the lens surface associated with accommodation (Figs. 46 and 47).

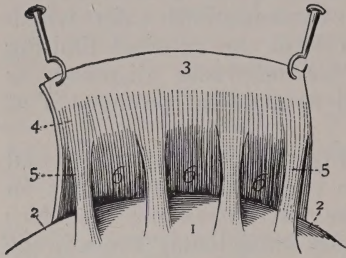


FIG. 46.—Diagrammatic view, from posterior surface, of the insertion of the zone of Zinn into the capsule of the lens (Testut): 1, posterior lens surface; 2, its equator; 3, zonula; 4, 5, the anterior and posterior bands, inserted into the corresponding surfaces of the lens-capsule; 6, the interfascicular spaces, formerly regarded as the canal of Petit.

Viewed from the posterior surface, the suspensory ligament appears as a delicate annular structure, about 6 mm. in width, which blends with the periphery of the lens on the one hand, and with the hyaloid membrane in the vicinity of the ora serrata on the other. When examined under low magnification in meridional sections of the ciliary region the suspensory ligament is seen to be not a continuous membrane, but an interlacing series of delicate fibers which bridge at various angles the space between the lens and the ciliary processes.

The older view, whereby the zone of Zinn was regarded as a direct continuation of the inner leaflet of the hyaloid membrane, formed by means of the cleavage which was supposed to take place in the vicinity of the ora serrata, has been now generally displaced by the newer teachings founded upon the more accurate studies of the developmental relations of the parts in question: according to these observations the hyaloid membrane does not undergo cleavage, but continues closely applied to the ciliary body, over which its attenuated extension stretches as far as the processes before fading away. The suspensory fibers constituting the zone of Zinn originate as independent structures, and genetically are closely related to the primitive vitreous body. Subsequently the zonular fibers become closely attached to the ora serrata as well as the hyaloid membrane, and seemingly take partial origin from these structures (Fig. 47).

The zonular fibers of the adult may be divided into *chief* and *accessory*. The chief zonular fibers, which constitute the principal union between the lens and the surrounding ciliary body, may be subdivided into *orbiculo-capsular* and *cilio-capsular* according to the position of their attachment to the ciliary body, whether to the orbiculus ciliaris or the ciliary processes. When traced to their attachment to the lens the fibers are found to vary in the position of their insertion into the capsule, some being fused in advance, others behind the lens periphery: these variations of attachment affect especially the orbicular group of zonular fibers, and hence their classification into the *orbiculo-antero-capsular* and the *orbiculo-postero-capsular* fibers, which pass from the ciliary ring to the anterior and posterior surfaces of the lens-capsule respectively. The fibers springing from the summits and sides of the ciliary processes join the lens-capsule either on the posterior surface or at the periphery, and are hence designated the *cilio-postero-capsular* or the *cilio-equatorial fibers*.

The accessory fibers are important additions to the strength of the suspensory ligament, since they comprise numerous shorter bands which act as braces and binders to the longer chief trabeculae. The accessory fibers are principally of two kinds—those which pass from the ciliary processes to the long zonular fibres, and those which extend from point to point within the ciliary zone. The first group includes numerous short bands which unite the

orbiculo-capsular fibers with the ciliary processes and ciliary ring; the second comprises especially the bands which have the fixation of the ciliary processes as their especial purpose, and constitute two principal groups—the *orbiculo-ciliary* and the *intraciliary* fibers.

The zone of Zinn, or the suspensory ligament, is evidently not a continuous membrane, but a series of interlacing bands between which numerous apertures and clefts occur. The insertion of the zonular fibers into the lens is so regular and the fibers bound together so intimately that it is possible to inject air between the constituents of the zone, so that the lens is surrounded

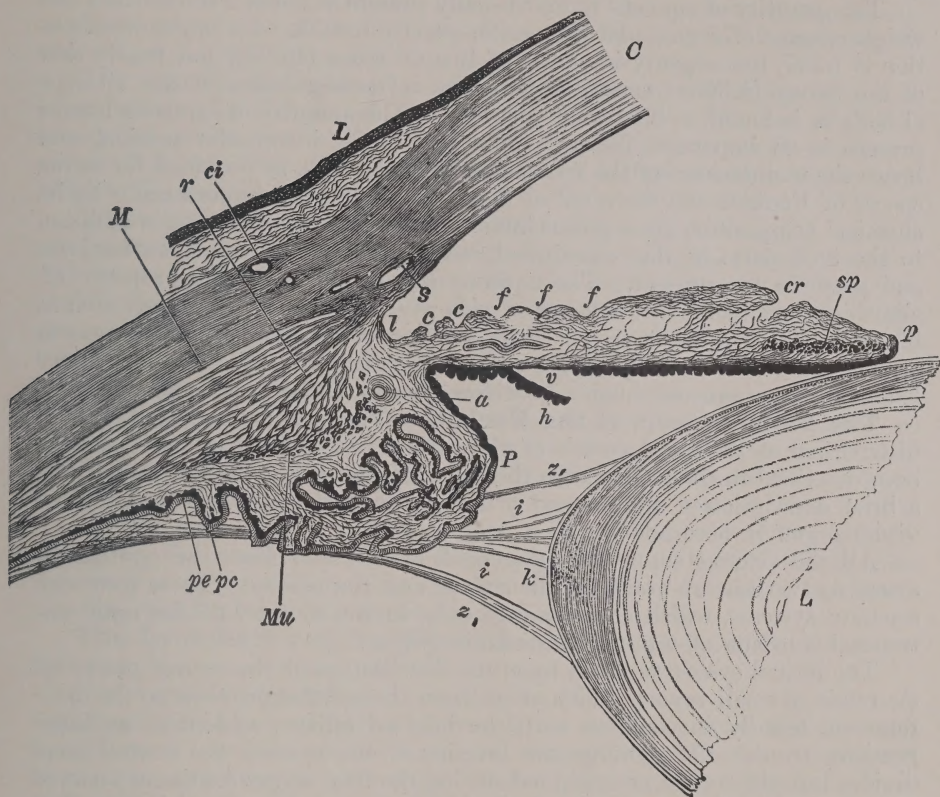


FIG. 47.—Meridional section through ciliary region, including part of the lens (Fuchs): *C*, cornea; *pe*, *pc*, pigmented and non-pigmented cells of the pars ciliaris retinae; *L*, lens; *M*, ciliary muscle; *r*, its radiating, *Mu*, its circular fibers; *ci*, anterior ciliary artery; *s*, canal of Schlemm; *z*, origin of ciliary muscle; *c*, *f*, anterior surface of iris; break at *cr*; *sp*, sphincter pupillae; *p*, edge of pupil; *P*, ciliary process; *h*, pigment lining iris, partly separated at *v*; *a*, blood-vessel; *z*, zone of Zinn; *z*₁, *z*₂, fibers of suspensory ligament, enclosing spaces *i*, *i*; *k*, lens-capsule.

by an annular series of beaded dilatations. This appearance was long accepted as demonstrating the existence of a delicate channel, the *canal of Petit*, encircling the periphery of the lens. With the more accurate understanding of the composition of the supporting apparatus of the lens the existence of the canal of Petit has become doubtful, and in the former sense of a closed annular channel altogether denied by most authorities. The intercommunicating spaces between the zonular fibers establishes a passageway for fluids from the posterior chamber into the vitreous chamber.

The Aqueous Humor.—The aqueous humor, the transparent lymph derived from the blood-vessels surrounding the spaces in which it is con-

tained, fills both the anterior and posterior chamber, as well as the extensions of the latter represented by the intrazonular spaces.

The production of the aqueous humor takes place in the posterior chamber, and is effected chiefly by the blood-vessels of the ciliary processes, and possibly also by those of the vascular ridges which extend to the posterior surface of the iris. The recesses between the ciliary processes have been regarded by some as representing special secreting tissue, the so-called "ciliary glands," but there is little evidence to sustain the view that in the secretion of the aqueous humor the entire ciliary processes do not take part.

The quantity of aqueous humor usually present is about 275 cub. mm., its weight about 0.275 gm., and its specific gravity 1.0053. Its index of refraction is 1.337, but slightly in excess of that of water (1.334), and nearly that of the cornea (1.360): compared with the refracting index of the vitreous (1.336), it is found to be almost identical. The quantity of aqueous humor present is an important factor in determining the intraocular tension, and hence the maintenance of the free escape of the lymph, as provided for in the spaces of Fontana and the canal of Schlemm, is of great importance. In its chemical composition the aqueous humor consists chiefly of water: in addition to the 98.6 parts of this constituent, small quantities of solids, extractives, and proteids are present. The aqueous humor possesses the property of absorbing certain organic substances with which it comes in contact, such as blood and the lens substance; it also possesses solvent properties to an extraordinary degree for many drugs. With the exception of a few migratory leukocytes, the aqueous humor is without morphological elements.

The Blood-vessels of the Eyeball.—The terminal arrangement and distribution of the blood-vessels of the various parts of the eye have already been described in connection with the consideration of the various structures: a brief description of the general arrangement of the vessels supplying the visual organ is here added.

All the arteries supplying the eyeball are derived from the ophthalmic artery as two sets of branches, the *retinal* and the *ciliary*. These form two separate systems, which communicate only in the vicinity of the optic entrance by means of minute anastomotic twigs.

The retinal system is based upon the distribution of the *central artery of the retina*, a small branch which arises from the ophthalmic close to the optic foramen, usually in common with the internal ciliary, seldom as an independent trunk. On gaining the interior of the eyeball the central stem divides into the retinal arteries, and during the fetal stages continues forward to the posterior lens surface as the hyaloid artery, a vessel which later disappears.

The ciliary system supplies the remaining parts of the eyeball, and consists of two sets of vessels, the *posterior* and *anterior ciliary arteries*. The posterior arise by two chief trunks, an *inner* and an *outer*, which are given off from the ophthalmic artery while it lies below the optic nerve. These stems each divide into from four to ten branches, which surround the optic nerve, and on reaching the eyeball pierce the sclerotic coat in the vicinity of the point of entrance of the nerve. The posterior ciliary arteries then form two groups—the *short*, which pass at once to the choroidal tract to take part in forming the rich vascular network of the middle tunic; and the *long*, which pass forward, one on each side of the eye, between the sclera and choroid, to the ciliary region, where, after giving direct branches to the ciliary muscle, they join the anterior ciliary arteries to form the vascular plexuses from which the adjacent parts are supplied.

The *anterior ciliary arteries*, usually from six to eight in number, are derived from the muscular and lachrymal branches of the ophthalmic; in the vicinity of the corneal margin they penetrate the scleral coat, and finally join the long posterior ciliary vessels to form the *circulus arteriosus iridis major*. Before passing through the sclerotic these arteries give off anterior and posterior branches which supply the conjunctiva and anterior parts of the fibrous tunic. After piercing the sclera twigs are given off which pass to the ciliary muscle, as well as others which as *recurrent branches*, together with similar branches from the long posterior ciliary arteries, anastomose with the choroidal vessels derived from the short ciliary trunks. An important anastomotic communication is thus established between the blood-vessels supplying the choroid proper and those distributed to the ciliary region.

The branches of the long posterior and the anterior ciliary arteries inosculate within the ciliary region to form in the vicinity of the root of the iris an arterial circuit, the *circulus arteriosus iridis major*, from which vessels are given off to the ciliary processes and the iris, as well as recurrent anastomotic twigs to the choroid.

The *venous trunks* draining the eyeball in general correspond in their arrangement to that of the arteries, the chief groups being the *retinal*, *posterior*, and *anterior ciliary* veins. The retinal veins receive the blood from the closed retinal system and follow closely the corresponding arteries. The posterior ciliary veins, or, more familiarly, the *venæ vorticosæ*, collect the blood from the iris, the ciliary processes, part of the ciliary muscle, the orbiculus ciliaris, and the choroid, and pierce the sclerotic coat within the equatorial region as four large trunks, which converge at points about equidistant from one another; after penetrating the fibrous tunic they additionally receive the episcleral veins. The anterior ciliary veins drain a much more limited area than that supplied by the corresponding arteries, since within the eyeball they receive only the blood returned from the ciliary muscle, taking up the small radicles communicating with Schlemm's canal: after emerging from the sclerotic coat the anterior ciliary veins receive as tributaries the episcleral and the anterior conjunctival vessels.

The Lymphatics of the Eyeball.—The lymph-channels of the eyeball comprise two systems, the *anterior* and the *posterior*.

The *anterior lymph-tract* embraces (1) the chambers occupied by the most important intraocular collection of lymph, the aqueous humor, together with the system of spaces by which this fluid is normally carried off, as represented by the spaces of Fontana and canal of Schlemm; and (2) the elaborate system of juice-channels within the cornea and adjacent part of the sclera. The *posterior lymph-tract* includes two separate systems, that of the choroid and of the retina. The lymphatic fluid of the choroid is collected within the *perichoroidal lymph-space*, between the choroid and the sclera, from which cleft the lymph escapes chiefly into the space of Tenon, or *episcleral lymph-space*, by means of the perivascular lymphatic canals accompanying the *venæ vorticosæ*: additional perivascular channels may also exist in connection with the posterior ciliary arteries. The accumulated lymph within the space of Tenon finds its way into the large intracranial lymph-spaces, probably by means of the supravaginal space which surrounds the exterior of the optic nerve. The retinal system of lymphatics is represented by the perivascular lymph-sheaths surrounding the retinal vessels, as well as by the hyaloid canal within the vitreous. These channels communicate with the lymph-clefts within the optic nerve, which are connected with the great intracranial lymph-spaces by means of the subarachnoidal spaces of the optic nerve.

GENERAL PHYSIOLOGY OF VISION.

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Introduction.—The visual apparatus in its entirety constitutes a mechanism the excitation of which gives rise (1) to the sensation of light and its different qualities—colors ; (2) to the perception of light and color under the form of pictures of external objects ; (3) to the production of muscular sensations by which we judge of the size, distance, and direction of objects. The specific physiological stimulus to the terminal apparatus of the optic nerve is the impact of the undulations of a perfectly elastic medium, the ether. The transfer of the energy of the ether-vibrations into that form of energy known as a nerve-impulse takes place in the pigment of the neuro-epithelial layer of the retina. The nerve-impulses so generated are transmitted by the fibers of the optic nerve to the cells of the cerebral cortex, in which some molecular process takes place out of which the mind forms the sensations of light and color. In general, it may be said that, at least for the same color, the intensity of the objective vibrations determines the intensity of the sensations.

The optic nerve, obeying the same general laws of nerve-stimulation, reacts also to the electric current and to mechanical agencies, as shown by flashes of light with varying shades of color.

The formation of images on the percipient elements of the retina, which by their forms and associated colors give rise to the perception of objects, is made possible by the introduction of a complex refracting apparatus consisting of the cornea, aqueous humor, crystalline lens, and vitreous humor. Without these agencies ether-vibrations would only give rise to a sensation of diffused luminosity. The movements of the eyeball occasioned by the contractions of the ocular muscles are attended by muscular sensations, out of which the mind draws its conclusions as to the size, distance, and direction of objects.

The Eye a Living Camera.—In its construction, in the arrangement of its various parts, and in their mode of action the eye may be compared to a *camera obscura*. Though the comparison may not be absolutely exact, yet in a general way it is true that there are many striking points of similarity between them—*e.g.* the sclera and choroid may be compared to the walls of the camera ; the combined refractive media to the single lens, the action of which results in the focussing of the light-rays ; the retina to the sensitive plate receiving the image formed at the focal point ; the iris to the diaphragm for the regulation of the amount of light to be admitted, and for the partial exclusion of those marginal rays which give rise to *spherical aberration* ; the ciliary muscle to the adjusting screw, by means of which the image is brought to a focus on the sensitive plate, notwithstanding the varying distances of the object from the lens. The presence of the *visual purple* in

the rods of the retina capable of being altered by light makes the comparison still more striking.

The Retinal Image.—The existence of an image on the retina can be readily seen in the excised eye of an albino rabbit, the coats of which are quite transparent from the absence of pigment. Its presence in the human eye can be demonstrated with the ophthalmoscope. It is this image, composed of focal points of luminous rays, which is the basis of our sight-perceptions, and which stimulates the rods and cones, and out of which the mind constructs space-relations of external objects. In only two essential respects does the image on the retina differ from the object, aside from the fact that the object has usually three, the image only two, dimensions—viz. in size and relative arrangement of its parts. Whatever the distance, the image is generally smaller than the object: it is also reversed, the upper part of the object becoming the lower part of the image, and the right side of the object the left of the image, and the reverse.

The Dioptric Apparatus.—The media by which rays of light entering the eye are refracted and brought to a focus with the production of an image consist of the cornea, aqueous humor, lens, and vitreous body. As the two surfaces of the cornea are practically parallel, and as the index of refraction of the aqueous humor is the same as that of the cornea, they may be regarded as but one medium. The refracting surfaces may therefore be reduced to the anterior surface of the cornea, the anterior surface of the lens, and the posterior surface of the lens.

Rays of light emanating from one point—that is, *homocentric rays*—entering the eye must traverse successively the different refractive media. In their passage from one to the other they undergo at their surfaces changes in direction before they are converged to a focal point. In order to mathematically follow the rays in all their deviations through the media, to determine their focal point, and to construct the image, a knowledge of the form of the refracting surfaces, the refractive index of the different media, and the distance of the surfaces from each other, must be obtained.

The following constants are now accepted: The radii of curvature of that portion of each refracting surface used for distinct vision are for the cornea 7.829 mm., for the anterior and posterior surfaces of the lens 10 and 6 mm., respectively. The indices of refraction of the different media are as follows: cornea and aqueous humor, 1.3365; lens, 1.4371; vitreous body, 1.3365. The distance from the vertex of the cornea to the lens is 3.6 mm.; the thickness of the lens, 3.6 mm.; the distance from the posterior surface of the lens to the retina, 15 mm.

Homocentric rays of light entering the eye pass from air with a refractive index of 1.00025 into the cornea with an index of 1.3365. In passing from the rarer into the denser medium they undergo refraction and are rendered somewhat convergent. The extent of this first refraction and convergence is sufficiently great to bring parallel rays, if continued, to a focus about 10 mm. behind the situation of the retina. On entering the lens they are for the same reason again refracted and converged, and if continued would come to a focus about 6.5 mm. behind the retina. On passing into the vitreous body they are again converged to an extent sufficient to focalize them on the retina (Fig. 48).

While it is possible thus to geometrically follow the rays through these media by means of the above-mentioned factors, the procedure is attended with many difficulties. Moreover, as the relations all change when rays enter the eye from objects situated progressively nearer the eye, a separate

calculation is necessitated for each distance for the determination of the size of the image.

A method by which these difficulties are much reduced was suggested by Gauss and developed by Listing. It was demonstrated by Gauss that in every complicated system of refracting media separated by spherical centered surfaces there may be assumed certain *ideal* or *cardinal points*, to which the system may be reduced, and which, if their relative position and properties be known, permit of the determination, either by calculation or geometrical construction, of the path of the refracted ray, and the position and size of the image in the last medium of the object in the first.

Every dioptric system can be replaced, as Gauss showed, by a single system composed of six cardinal points and six planes perpendicular to the

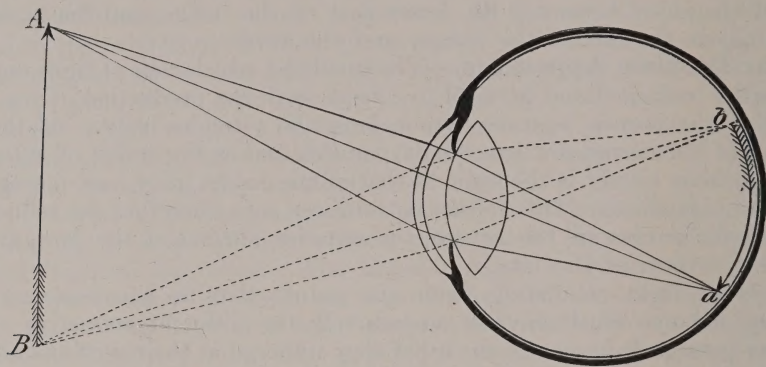


FIG. 48.—Refraction of homocentric rays and the formation of images on the retina.

common axis—*e. g.* two focal points, two principal points, two nodal points, two focal planes, two principal planes, and two nodal planes.

Properties of the Cardinal Points.¹—The *first focal point*, F_1 in Fig. 49, has the property that every ray which before refraction passes through it after refraction is parallel to the axis.

The *second focal point*, F_2 , has the property that every ray which before refraction is parallel to the axis passes after refraction through it.

The *second principal point*, H_2 , is the image of the *first*, H_1 ; that is, rays in the first medium which go through the first principal point pass after the last refraction through the second. Planes at right angles to the axis at these points are *principal planes*. The second principal plane is the image of the first. Every point in the first principal plane has its image after refraction at a corresponding point in the second principal plane at the same distance from the axis and on the same side.

The *second nodal point*, N_2 , is the image of the *first*, N_1 : a ray which in the first medium is directed to the first nodal point passes after refraction through the second nodal point, and the directions of the rays before and after refraction are parallel to each other. In Fig. 49 let AB represent the axis. The distance of the first focal point, F_1 , from the first principal plane, H_1 , is the *anterior focal distance*. The distance of the posterior focal point, F_2 , from the second principal plane, H_2 , is the *posterior focal distance*. The distance of the first nodal point, N_1 , from the first focal point is equal to the second focal distance. The distance of the second nodal point, N_2 , from the posterior focal point is equal to the anterior focal distance. It is evi-

¹ For additional consideration of this subject see pages 109 and 125.

dent, therefore, that the distance of the corresponding principal and nodal points from each other is equal to the differences between the two focal distances. Also the distance of the two principal points from each other is equal to the distance of the two nodal points from each other. Finally, the

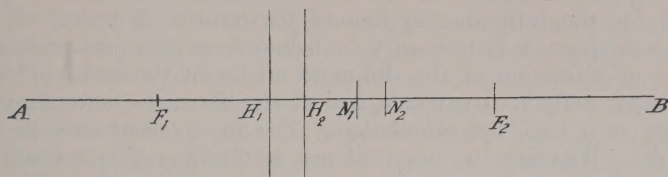


FIG. 49.—Diagram showing the position and relation of the cardinal points.

focal distances are proportional to the refractive indices of the first and last media. Planes passing through the focal points vertically to the axis are known as *focal planes*.

From these properties of the cardinal points the position of an image in

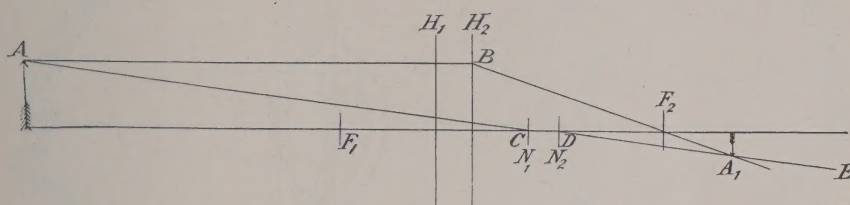


FIG. 50.—Diagram to find the image in last medium of a luminous point in the first.

the last medium of a luminous point in the first may be determined, and the course of a refracted ray in the last medium be constructed if its direction in the first be given according to the following rules:

1. To find the image in the last medium of a luminous point in the first:

Let A (Fig. 50) be this given point. Draw AB parallel to the axis until it meets the second principal plane in B ; then BF_2 will be this ray after refraction. Draw a second ray from A to the first nodal point; then draw another ray, DE , from the second nodal point parallel to AC . This will be the refracted ray in the last medium. Where the two refracted rays, BF_2 and DE , intersect, the image of A will be A_1 .*

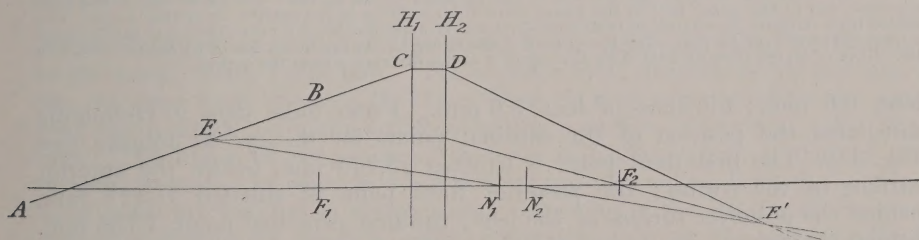


FIG. 51.—Diagram to find the refracted ray in the last medium of a given ray in the first medium.

2. To find the refracted ray in the last medium of a given ray in the first medium:
Let AB (Fig. 51) be the given ray. Continue this ray until it meets the first prin-

* If the point A is infinitely far from the eye, all the rays striking the eye will be parallel to each other. The nodal ray must therefore be drawn, and the point where this nodal ray meets the second focal plane will be the image of $A = A_1$, where all rays parallel to the nodal ray will meet.

cipal plane in C . Draw CD parallel to the axis. Now assume any point, such as E , in the given ray, and find its image E_1 by the Rule 1. Then DE_1 becomes the course of the refracted ray.

The Schematic Eye.—Accepting the system of cardinal points, Listing, Donders, and v. Helmholtz have constructed “schematic” eyes to be substituted for the refracting system of the natural eye.

For this purpose it is necessary to deduce from the various estimates of the indices of refraction of the different media, of the radii of curvatures of the different refractive surfaces, and of the distances separating them an average eye as a basis for calculation. The most recent attempt is that of v. Helmholtz. The data he assumed are as follows: The refractive index of air = 1; of the cornea and aqueous humor, 1.3365; of the lens, 1.4371; of the vitreous humor, 1.3365; the radius of curvature of the cornea, 7.829 mm.; of the anterior surface of the lens, 10 mm.; of the posterior surface, 6 mm.; the distance from the apex of the cornea to the anterior surface of the

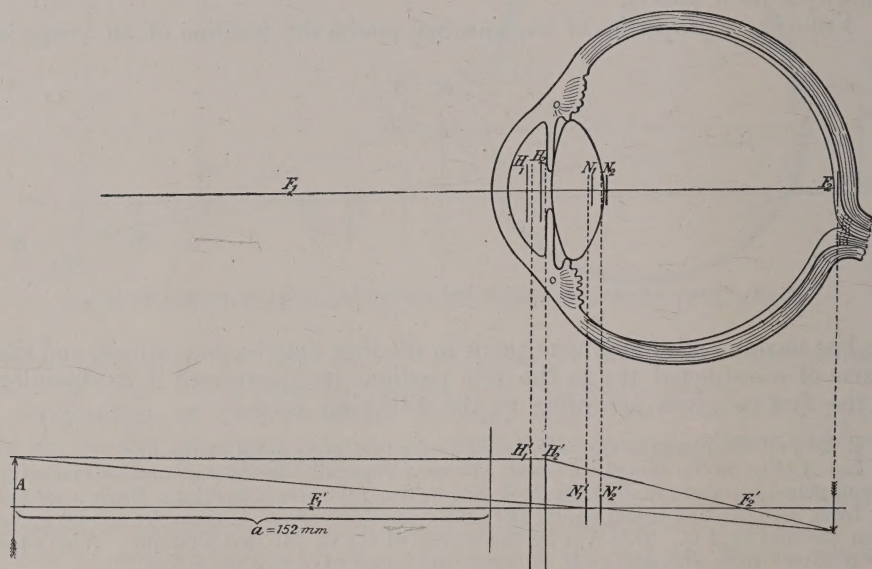


FIG. 52.—Diagram showing the position of the cardinal points in the “schematic eye.” The continuous lines in the upper half of the figure show their position in the passive emmetropic eye. The dotted lines indicate the change in their position in an eye accommodated for the object A at the distance a from the cornea, or 152 mm. The lower half of the figure shows the formation of a distinct image on the retina of an eye accommodated for the object A at the distance a from the cornea.

lens, 3.6 mm.; thickness of lens, 3.6 mm. From these data v. Helmholtz calculated the position of the cardinal points for the eye as follows (see Fig. 52): The first focal point is situated 13.745 mm. before the anterior surface of the cornea; the posterior focal point is situated 15.619 mm. behind the posterior surface of the lens; the first principal point, 1.753 mm. behind the cornea; the second principal point, 2.106 mm. behind the cornea; the first and second nodal points, 6.968 and 7.321 mm. behind the apex of the cornea, respectively. The anterior focal distance of this schematic eye therefore amounts to 15.498 mm., and the posterior focal distance to 20.713 mm.

When the eye, however, is accommodated for near vision, the relations of the cardinal points are changed as follows, if the point accommodated for lies 152 mm. from the cornea: Anterior focal distance, 13.990 mm.; posterior focal distance, 18.689 mm.; distance from cornea of the first and second

principal points, 1.858 and 2.257 mm. respectively; distance of the posterior focus, 20.955 mm. from cornea. Given this schematic eye in the accommodated state, the course of the rays and the determination of the position of an image in the last medium of a luminous point in the first can easily be determined by the rules above given.

The Reduced Eye.—As suggested by Listing, this schematic eye may be yet further simplified or reduced to a single refracting surface bounded anteriorly by air and posteriorly by aqueous or vitreous humor. Without introducing any noticeable error in the determination of the size of the retinal image, the anterior principal and the anterior nodal points may be disregarded, owing to the minuteness of the distances (0.39 mm.) separating the two systems of points. There is thus obtained one principal point and one nodal point, which latter becomes the center of curvature of the single refracting surface. The dimensions of this "reduced" eye are as follows (see Fig. 53):

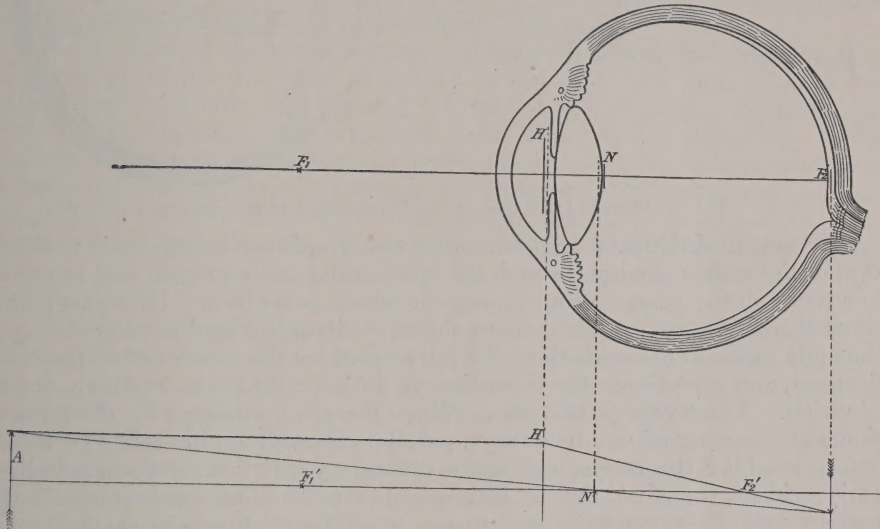


FIG. 53.—Diagram showing the position of the cardinal points in the "reduced eye." The continuous lines in the upper half of the figure show their position in the passive eye. The dotted lines refer to their change of position when the eye is accommodated for the near object, A . The lower half of the figure shows the formation of an image in the reduced eye and the relation between the size of the object and the size of the image.

From the anterior surface of the cornea to the principal point, 2.106 mm.; to the nodal point, 7.321 mm. The anterior focal distance is 15.498 mm.; the posterior focal distance, 20.713. There is thus substituted for the natural eye a single refracting surface having a radius of curvature of 5.215 mm. The index of refraction of this eye is 1.3365, which is that of the vitreous humor. In such an eye luminous rays emanating from the anterior focal point are parallel to the axis after refraction in the interior of the eye. Also rays parallel to the axis before refraction unite at the posterior focal point. By means of this reduced eye the construction of the refracted ray, the various calculations as to the size of the image, the size of diffusion circles, etc. are much facilitated.

In Fig. 54 let AB represent an object. From A homocentric rays fall on the single refracting surface H . One of the rays, the nodal ray, falling on the surface perpendicularly, passes unrefracted through the single nodal point, N , to the posterior focal plane. The remaining rays, falling on this surface under varying degrees of incidence, undergo corresponding degrees of refraction, by which they form a converging cone of

rays which unite at a point situated on the nodal ray. These two points are known as *conjugate foci*. The same holds true for homocentric rays emanating from *B* or any other point of the object.

The size of the retinal image, *I*, may now be easily calculated, when the size of the object, *O*, and its distance, *D*, from the refracting surface with radius of curvature, *R*, are known, by the following formula:

$$O:I = D + R : F_2 - R.$$

For, as the triangles *A N B* and *a N b* are equal, we have

$$A B : a b = f N : N g, \text{ or } a b = \frac{A B \times N g}{f N}.$$

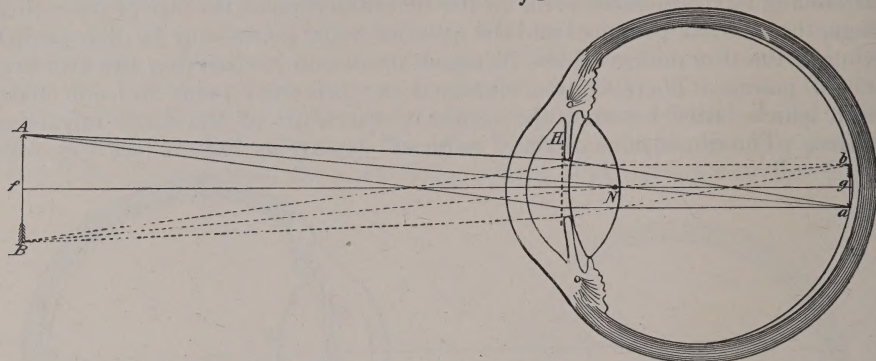


FIG. 54.—Diagram to illustrate formation of images in reduced eye.

Accommodation.¹—In a normal or *emmetropic* eye homocentric parallel rays of light after passing through the optic media are converged and brought to a focus on the retina. Rays, however, which come from a luminous point situated near the eye, and which are therefore divergent and passing through the optic media at the same time, are intercepted by the retina before they are focussed, and give rise to the formation of diffusion-circles and indistinctness of vision. The reverse is also true. When the eye is adjusted for the refraction and focussing of divergent rays, parallel rays will be brought to a focus before reaching the retina, and, again diverging, will form diffusion-circles. It is evident, therefore, that it is impossible to simultaneously focus both parallel and divergent rays, and to see two objects distinctly at the same time which are situated at different distances. The eye must be alternately adjusted first to one object and then to another. The capability which the eye possesses of adjusting itself to vision at different distances is termed *accommodation*.

The following table of Listing shows the size of the diffusion-circles formed of objects situated at different distances when the accommodative power is suspended:

Distance of luminous point.		Distance of the focal point behind the posterior surface of the retina.		Diameter of the diffusion-circle.	
∞		0.	mm.	0.	mm.
65	m.	0.005	"	0.0011	"
25	"	0.012	"	0.0027	"
12	"	0.025	"	0.0056	"
6	"	0.050	"	0.0112	"
3	"	0.100	"	0.0222	"
1.500	"	0.20	"	0.0443	"
0.750	"	0.40	"	0.0825	"
0.375	"	0.80	"	0.1616	"
0.188	"	1.60	"	0.3122	"
0.094	"	3.20	"	0.5768	"
0.088	"	3.42	"	0.6484	"

¹ For additional consideration of this subject consult page 134 and page 155.

The normal eye when adjusted for distant vision is in a passive condition and unattended with fatigue. In the act of adjustment, however, for near vision the eye passes into an active state, the result of a muscular effort, the energy of which is proportional to the nearness of the object toward which the eye is directed. From the above table it is evident that rays of light coming from infinity or from any object even but 6 m. distant are so nearly parallel and the diffusion circles so very small that the indistinctness of the image is scarcely perceived, and hence no perceptible accommodative effort is required. Rays coming from objects situated progressively nearer the eye require for their focalization a constantly increasing effort of accommodation. During accommodation the lens undergoes a change of shape, becoming more convex, especially on its anterior surface. The greater the degrees of divergence of the rays the greater must be the increase in lens convexity, in order that they may be sufficiently converged and focalized on the retinal surface. Changes in the curvatures of the lens, either of increase or decrease, are attended with corresponding changes in the distinctness of the image.

Mechanism of Accommodation.—Though it is generally admitted that the increase in the convexity of the lens is caused by the contraction of the ciliary muscle and the subsequent relaxation of the suspensory ligament, the exact manner in which this is brought about is not well understood. When the eye is in repose and adjusted for distant vision the lens is somewhat flattened from the traction of the suspensory ligament. When the eye requires adjustment for near vision the ciliary muscle contracts, the suspensory ligament relaxes, and the lens, in consequence of its inherent elasticity, bulges forward and becomes more convex. Its antero-posterior diameter is thus increased and its refractive power is proportionally greater.

It is generally admitted that during accommodation the meridional fibers of the ciliary muscle draw forward the ciliary processes and relax the ligament. At the same time the outer border of the iris is drawn somewhat backward. In extreme efforts of accommodation it is also believed by some observers that the circular fibers, the so-called “annular muscle,” contract and exert a pressure on the periphery of the lens, and thus aid other mechanisms in increasing the convexity. This view appears to be supported by the fact that in hyperopia, where there is a constant effort required for distinct vision even of distant objects, the annular muscle becomes very much hypertrophied, thus serving to reinforce the action of the meridional fibers. In myopia, on the contrary, where the accommodative effort is at a minimum, the entire muscle possesses less than its average size and development (compare with page 135).

Optical Defects.¹—From a purely physical point of view the eye is not a perfect instrument. It is not quite achromatic, is not free from spherical aberration, and is not exactly centered. Moreover, its area of distinct vision is quite limited, and does not correspond with the field of projection, the retina. In first-class optical instruments the lenses are centered—that is, their exact centers are situated on the same axis. In viewing an object through such a system the visual line corresponds with the axis of the lens-system. This is not the case with the lens-system of the eye.

A line passing through the center of the cornea and the center of the eye, the *optic axis* OA in Fig. 55, does not pass exactly through the center of the lens, and does not fall into the point of most distinct vision, the fovea. This

¹ For a full consideration of the optical defects of the eye, see sections devoted to Optics and Refraction.

has led to the recognition of other lines, the relations of which must be borne in mind in all optical discussions.

1. The *visual axis*, or line of vision VL , is the line connecting the point viewed, the nodal point, and the fovea centralis.

2. The *line of fixation*, or line of regard VC , is the line connecting the point viewed with the *center of rotation*, the latter being situated 6 mm. behind the nodal point of the eye and 9 before the retina. The relations of these lines and certain angles in connection with them are shown in the following figure :

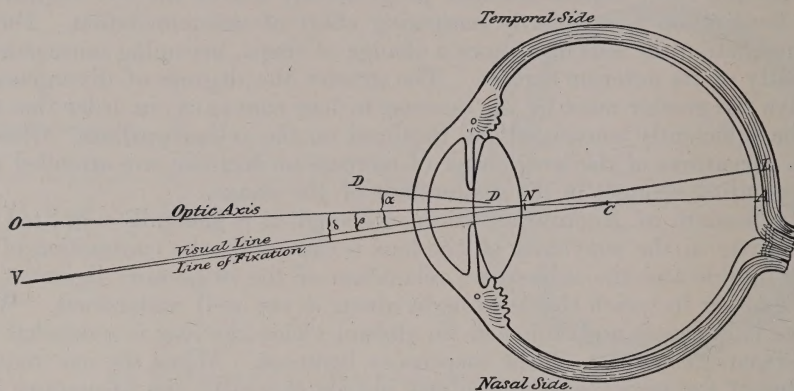


FIG. 55.—Diagram showing the corneal axis DD , the optic axis OA , the visual axis VL , and the line of fixation VC ; also the three angles α , β , γ .

The angle included between the line DD (the major axis of the corneal ellipse) and the visual line is the *angle alpha*, amounting, on the average, to about 5° . The angle included between the optic axis and the line of regard is known as the *angle gamma*, while the angle between the optic axis and the line of vision is known as the *angle beta* (see also page 129).

Functions of the Iris.—The iris, in virtue of the capability it possesses of alternately enlarging and diminishing the size of its central opening, the *pupil*, forms in several respects an important corrective apparatus of the eye. It serves as a diaphragm by which the rays of light which would otherwise pass through the margin of the lens are cut off, so that *spherical aberration* is in a great measure overcome. It also serves, through the contraction of its muscular fibers, to form a fixed point of support for the ciliary muscle during the period of active accommodation. Owing to the fact that the circular fibers of the iris alternately contract and relax with increasing and decreasing intensities of light, it serves to regulate the amount of light entering the eye necessary for distinct vision. In the absence of light the *sphincter pupillæ* relaxes and the pupil enlarges. As the light increases in intensity the muscle contracts and the pupil becomes smaller. The contraction of the sphincter muscle is with a given intensity of light greater when the light falls directly into the fovea. Contraction of this muscle also occurs as an associated movement in the act of convergence of the optic axes in accommodative efforts and in consensus with the other eye.

The movements of the iris by which the size of the pupil is determined from moment to moment are caused by the contractions of the *sphincter pupillæ* and *dilatator pupillæ* muscles. The contraction of the sphincter is entirely reflex and involves for its action the parts necessary to the performance of any reflex act—viz. a sentient surface, the retina; an afferent nerve, the optic; a central center situated in the gray matter of the aqueduct of

Sylvius; and an efferent nerve, the motor oculi. The stimulus requisite for the calling forth of a contraction is the impact of ether-vibrations on the ends of the rods and cones. According to the intensity of the light or ether-vibrations will be the energy of the contraction. The contraction of the *dilatator pupillæ* is determined by the activity of a continuously active nerve-center situated in the medulla oblongata, which transmits its regulative nerve-impulses to the iris through fibers in the sympathetic.

The exact course of these fibers, however, in man is not satisfactorily determined. From their origin they pass successively through the cervical cord, the anterior roots of the first and second dorsal nerves, the upper thoracic ganglion, the cervical sympathetic, the upper cervical ganglion through fibers to the ophthalmic division of the fifth nerve, the nasal nerve, and long ciliary nerve to the iris.

As to the action of the two sets of muscles, they appear to bear an antagonistic relation to each other, for section of the motor oculi is followed by relaxation of the circular fibers and dilatation of the pupil. Stimulation of the sympathetic in the neck is followed by a much larger dilatation of the pupil. The normal physiological stimulus to the dilator center is probably dyspneic blood, though it is excited by muscular activity and stimulation of various sensory nerves.

Functions of the Retina.—Of all the layers of the retina, the rods and cones appear to be the most essential to vision. It is only this layer which is capable of receiving the light-stimulus and of transforming it into some specific form of energy, which in turn arouses in the fibers of the optic nerve the characteristic nerve-impulses. The nerve-fibers themselves are insensible to the impact of the ether-vibrations, and require for their excitation some intermediate form of energy. That this is the case was shown by Donders, who reflected a beam of light on the optic nerve at its entrance without the individual experiencing any sensation of light. This region, occupied only by the optic-nerve fibers and devoid of any special retinal elements, is therefore an insensitive or blind spot. The diameter of this spot is about 1.5 mm., and occupies in the field of vision a space of about 6°. It is situated about 3.5 mm. to the nasal side of the visual axis. Its existence can be demonstrated by the familiar experiment of Mariotte—*e. g.* if the right eye be directed to the cross in the following figure (56) and the



FIG. 56.—To demonstrate the blind spot.

left eye closed, and the paper be held at a distance of 10 inches, the circle will entirely disappear. This occurs when the image falls on the optic nerve at its entrance. (See also page 470.) The experiment of Purkinje demonstrates the same fact.

It is well known that the blood-vessels of the retina are situated in its innermost layers a short distance behind the optic-nerve fibers. Owing to this anatomical arrangement, a portion of the light coming through the pupil will be intercepted by the vessels and a shadow projected on the layer of rods and cones. Ordinarily, these shadows are not perceived, for the reason

that the shaded parts are more sensitive and their excitability less readily exhausted, and perhaps because the mind has learned to disregard them. But if light be made to enter the eye obliquely, the position of the shadows will be changed, when at once they become apparent. This can be shown in the following way :

If in a darkened room a lighted candle be held several inches to the side and to the front of the eye, and then moved up and down, there will be perceived, apparently in the field of vision, an arborescent figure corresponding to the retinal blood-vessels. This is due to the falling of the shadows on unusual portions of the layer of rods and cones (see also page 141).

Excitability of the Retina.—The retina is not equally excitable in all parts of its extent. The maximum degree of sensibility is found in the macula lutea, and especially in its central portion, the fovea. In this region the layers of the retina almost entirely disappear, the layer of rods and cones only remaining, and in the fovea only the latter are present. That this area is the point of most distinct vision is shown by the observation that when the eye is directed to any given point of light, its image always falls in the fovea. Any pathological change in the fovea is attended by marked indistinctness of vision. The sensibility of the retina gradually but irregularly diminishes from the macula toward the periphery. This diminution in sensibility holds true for monochromatic as well as white light.

As stated above, the nature of the molecular processes which take place in the retinal tissue, and which are caused on one hand by the light-vibrations, and on the other hand develop nerve-impulses, is entirely unknown. The discovery of the *visual purple* in the outer segment of the rods gave promise of some explanation of the process, especially when it was shown to undergo changes when exposed to the action of light. Kühne even succeeded in obtaining an *optogram*, or a fixed image, of an external object in a manner similar to that by which an image is fixed on the sensitive plate of a camera. But as the pigment is wanting in the cones, and especially in the fovea, it cannot be considered essential to distinct vision, although that it plays some important rôle in the visual process is highly probable. The visual purple disappears when the eye is exposed to light, but is restored when light is excluded. It has also been observed that under the influence of light-stimulation the cones become shorter, and in the darkness again become longer (see page 69).

Color-perception.—A beam of sunlight passed through a glass prism is decomposed into a series of colors—red, orange, yellow, green, blue, indigo, and violet—the so-called *spectral colors*, so well exemplified in the rainbow. The spectral colors are termed *simple colors*, because they cannot be any further decomposed by a prism. Objectively, the spectral colors consist of very rapid transverse vibrations of the ether, from about 400 millions of millions per second for red to about 760 millions of millions for violet, but subjectively they are sensations caused by the impact of the ether-waves on the percipient layer of the retina.

It is possible to mix or blend these spectral color-sensations in the eye by stimulating the same area of the retina by different spectral colors, either at the same time or in rapid succession. The following table shows the results of such experiments as performed by v. Helmholtz (Dk. = dark ; Wh. = whitish).

	Violet.	Indigo.	Cyan-blue.	Bluish-green.	Green.	Greenish-yellow.	Yellow.
Red	Purple	Dk.-rose	Wh.-rose	White	Wh.-yellow	Gold-yellow	Orange
Orange	Dk.-rose	Wh.-rose	White	Wh.-yellow	Yellow	Yellow	. .
Yellow	Wh.-rose	White	Wh.-green	Wh.-yellow	Gr.-yellow	. .	. .
Gr.-yellow	White	Wh.-green	Wh.-green	Green	. .	. .	. .
Green	White-blue	Water-blue	Bl.-green	. .	. .	. .	. .
Bluish-green	Water-blue	Water-blue	. .	. .	. .	. .	. .
Cyan-blue	Indigo	. .	. .	. .	. .	. .	. .

These are the *mixed colors*. But it is to be observed that only two new color-sensations can be produced, white and purple, the remaining mixed colors already finding their equivalent in the spectrum. White and purple, therefore, are color-sensations, which have no objective equivalent in a simple number of ether-vibrations like the spectral colors.

Two spectral colors which by their mixture produce the sensation of white are called *complementary colors*. Such are red and green-blue, golden yellow and blue, green and purple. The mixture of all the spectral colors produces white again. This is the result of adding two or more *color-sensations*. Different results are obtained, however, by adding colored *pigments*. Yellow and blue, for example, produce in the eye white, but on the painter's palette green. For the explanation of such facts reference must be made to larger treatises. The colors of nature are usually mixtures of simple colors, as can be shown by spectroscopic analysis or by a synthesis of spectral colors.

In all color-sensations we must distinguish three primary qualities: (1) hue; (2) purity or tint; (3) brightness or luminosity. The first quality gives the main name to the color—*e. g.* red or blue—this depending on the spectral color or the mixture of two spectral colors with which it can be matched. The second quality, the tint, depends on the admixture of white to the ground color; and the third quality, brightness, depends on the objective intensity of the light and the subjective sensitiveness of the retina. Color-perception thus far refers only to the most sensitive part of the retina. At the more peripheral parts of the retina the colors are seen somewhat differently, as is shown by the following table giving the limits up to which the colors are recognized:¹

	White.	Blue.	Red.	Green.
Externally	90°	80°	65°	50°
Internally	60°	55°	50°	40°
Superiorly	45°	40°	35°	30°
Inferiorly	70°	60°	45°	35°

Theories of Color-perception.—The *theory of v. Helmholtz*, originated by Thomas Young (1807), assumes in its latest form the existence in the human retina of three different kinds of end organs, each of which is loaded with its own photo-chemical substance capable of being decomposed by a certain color, and thus exciting the fiber of the optic nerve.

In the first group these end organs are loaded with a red-sensitive substance, which is affected mainly by the red part of the spectrum; the second group has its end organs provided with a green-sensitive substance, which is mainly excited by the green color; while the third group is provided with a blue-sensitive substance, this latter being mainly affected and decomposed by the blue-violet portion of the spectrum. All these three different end organs are present in every part of the most sensitive area of the retina, and are connected by separate nerve-fibers with special parts of the brain, in the cells of which each calls up its separate sensation of red or green or blue.

¹ For further discussion of this subject see page 167.

Out of these three primary color-sensations all other color-sensations arise. If a light mainly excites the red- or green- or blue-sensitive substance of a retinal area, we term it red, green, or blue, respectively. But if two of these photo-chemical substances are stimulated simultaneously, quite different sensations arise. Thus simultaneous stimulation of the red and green substances gives rise to the sensation of yellow, that of red and blue to the sensation of purple, and that of blue and green to the sensation of blue-green. Simultaneous stimulation of all three substances of a certain area produces the sensation of white. According to this theory, complementary colors are all those which together excite all the three substances. *Color-blindness* is explained by this theory, on the assumption that two of the photo-chemical substances have become similar or equal in composition to each other.

The *theory of Hering*, brought forward in 1874, has the underlying assumption that the process of restitution in a nerve-element is capable of exciting a sensation. This theory asserts that there are three visual substances in the retina—a white-black, a red-green, and a yellow-blue visual substance. A destructive process in the white-black substance, such as is induced not only by white light, but also by any other simple or mixed color, produces the sensation of white, while the process of restitution or assimilation in this substance produces the sensation of black. Similarly, red light produces disassimilation or decomposition in the red-green substance, and this, again, the sensation of red. Green light, however, favors the process of restitution or assimilation in the red-green substances, and thus gives rise to the sensation of green. In the same way the sensation of yellow has its cause in the decomposition of the yellow-blue substance induced by yellow light, while the sensation of blue is produced by an assimilative process in the same substance. Simultaneous processes of disassimilation and assimilation in the same visual substance antagonize each other, and consequently produce no color-sensation by means of this substance, but only the sensation of white, by reason of decomposition, by both colors, in the white-black substance. Thus, yellow and blue, impinging on the same retinal area, have no effect on the yellow-blue substance, because they are antagonistic in their action on this substance, but only produce the sensation of white, as both yellow and blue decompose the white-black material. *Color-blindness* is explained by the assumption of the absence of either the red-green or the yellow-blue visual substance in the retina.

Movements of the Eyeball.—The almost spherical eyeball lies in a correspondingly shaped cavity of the orbit, like a ball placed in a socket, and is capable of being moved to a considerable extent by the six ocular muscles which are attached to it. The movements of each eye are referred to three fixed lines or axes which have their origin at the point of rotation of the eyeball, this point lying about 1.7 mm. behind the center of the globe. If the eye looks straight forward in the horizontal plane (the head being erect), the line joining the center of rotation with the object looked at is the *visual line* or *visual axis*. Around this antero-posterior axis the eye may be regarded as performing its circular *rotation* or *torsion*. At right angles to this line, and joining the center of rotation of both eyes, is the *horizontal* or *transverse axis* around which the movements of elevation (up to 34°) and depression (down to 57°) take place. At right angles to both of these lines there is the *vertical axis*, around which the movements of adduction (toward the nose up to 45°) and abduction (toward the temple up to 42°) occur. The six muscles may be divided into three pairs, each of which has a common axis around which it tends to move the eyeball. But only the common axis of the internal and

external recti coincides with one of three axes before mentioned—namely, with the vertical axis—thus moving the ball only inwardly or outwardly, respectively. The other two pairs, however, have their own axes of action, and their movements of the ball must be therefore analyzed with regard to all the three axes, each of these four muscles producing rotation, elevation, and depression, and abduction or adduction. The superior and inferior recti muscles, forming one pair, move the eye around a horizontal axis which intersects the median plane of the body in front of the eyes at an angle of 63° , and the superior and inferior oblique muscles forming the third pair rotate the globe around a horizontal axis which cuts the median plane of the body behind the eyes at an angle of 39° . Thus it is that each muscle moves the eye as follows, the movement for practical purposes being referred to the cornea: The rectus externus draws the cornea simply to the temporal side, the rectus internus simply to the nose; the superior rectus displaces the cornea upward, slightly inward, and turns the upper part toward the nose (medial torsion); the inferior rectus moves the cornea downward, slightly inward, and twists the upper part away from the nose (lateral torsion); the superior oblique displaces the cornea downward, slightly outward, and produces medial torsion; while the inferior oblique moves the cornea upward, slightly outward, and produces lateral torsion. These facts show that for certain movements of the eye at least three muscles are necessary (see following table):

Inward,	Rectus internus.	Inward and	{ Rectus internus.
Outward,	Rectus externus.	downward,	{ Rectus inferior.
Upward,	{ Rectus superior.		{ Obliquus superior.
	{ Obliquus inferior.	Outward and	{ Rectus externus.
Downward,	{ Rectus inferior.	upward,	{ Rectus superior.
	{ Obliquus superior.		{ Obliquus inferior.
Inward and	{ Rectus internus.	Outward and	{ Rectus externus.
upward,	{ Rectus superior.	downward,	{ Rectus inferior.
	{ Obliquus inferior.		{ Obliquus superior.

If both eyes have their line of vision in the horizontal plane parallel with each other and with the median plane of the body, they are said to be in the *primary position*. All other positions are called *secondary*. Both eyes always move simultaneously, which is called the *associated movement of the eyes*. There are three forms of associated movements: (1) movement of both eyes in the same direction; (2) movements of convergence by which the visual lines are converged on a point in the middle line of the body; (3) movements of divergence, by which the eyes are brought back from convergence to parallelism, or even to divergence, as in certain stereoscopic exercises. A combination of (1) and (2) or of (1) and (3) takes place for certain positions of the object looked at.¹

¹ For further and similar consideration of the physiological action of the ocular muscles see pages 41, 42, 497, and 498.

GENERAL OPTICAL PRINCIPLES:

KATOPTRICS, DIOPTRICS, PHYSIOLOGICAL OPTICS.

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Light from its source spreads from center to circumference—not as the arrow flies, but as the wave passes. The continually repeated cycle at the origin is imitated in all its essentials at each surrounding particle, which, being thus made luminous, transmits in turn what it has received to others next removed.

This is not the place to discuss at length the wave theory of light, but let it be remembered that the image on the retina is the result of purely mechanical processes into which the time element necessarily enters. Whatever the nature of the cycle at the origin, it has to do with a mass of matter controlled by elastic forces, hence its period is constant. The conditions at half-cycle periods are such as may be represented by algebraic equals and opposites, compounding into zero if both are impressed on the same body at the same time.

The passage of light through space is the transference of motion from one body to another, or to many others whose reactions bring or tend to bring the first to rest, and which are brought to rest in turn by those on whom they act.

The time element in this process of light propagation is also determined strictly in accordance with mechanical laws, and hence the spherical shell of a wave-surface is deformed or distorted by any change in the density or structure of the medium through which it passes.

At the outset, in a homogeneous medium, the wave-surfaces are spherical, and the light received by any body to which the wave has reached is measured by the area of wave-surface which it intercepts. This means that the body is, as it were, a buffer to the moving masses of which the medium is composed.

If the recipient is at an equal distance from two such sources of light whose phases and cycles are similar, it will of course receive twice the light that it would from one. Now, the whole theory of transmission by waves implies that every separate point of a wave-front is itself, while the wave is passing, nothing other than an instantaneous source of light, and may be treated as such, and that the results traceable to any one luminous element (Fig. 57, l) are the same as may be obtained by the summation of results

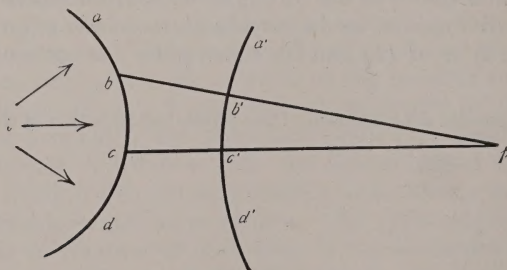


FIG. 57.—To illustrate the fact that when the center of a wave-surface is behind the wave, it is a radiant; when in front of the wave, it is a focus.

due to similar conditions as they exist at some later period in every separate element, a, b, c, d , etc., along the whole wave-surface. Thus it happens that any point, p , equally distant from the points, b and c , receives double the amount of light or energy from both these points that it does from either.

A change in the form of the wave-front so that, as at a' , d' , it curves in a circle about the point p toward which it is advancing, makes that point the recipient of all the energy which was distributed along its arc.

Image-forming optical instruments are devices by which each light-wave that comes from one of a configuration of points, *the object*, is made to curve around the corresponding one of another configuration of points, *the image*.

Fig. 58 delineates this process in its simplicity, where a lens is made of such medium as will delay by its density the progress of the wave, and is so shaped that it will give

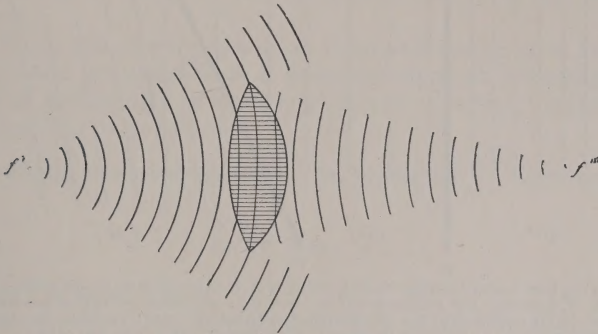


FIG. 58.—Showing the physical relation of a lens to its conjugate foci: f' , radiant: f'' , focus conjugate to f' .

to the wave-front a circular section. The ray, as indicative of the direction toward which the wave at any point is moving, is identical with the radius of the curved wave-surface at that point, and the radius of a circle measures its straightness of arc, just as the reciprocal of the radius measures its curvature.

Thus it will be seen that the study of the propagation and distribution of light is very much, at bottom, the study of curves, and, as curves are determined by the properties of their normals or radii, it is possible for *Geometrical Optics* to be cultivated as a degenerate form of *Physical Optics*, dealing principally with the positions of points and the lengths of line-segments.

The accessibility of certain truths when sought by geometrical methods, and the accessibility of the methods themselves as instruments of research, are their all-sufficient but not their only recommendation. In the pages that follow only occasional reference will be made to the physical aspects of the case, but attention is here invited to the fact that not only as a figure of speech, but in the accurate mathematical sense, *rarity* is the reciprocal of *density*, *straightness of curvature*, and *slowness of velocity*. From these hints it will be found that the formulæ used in the study of refracting and reflecting surfaces and centered lens-systems give abundant evidence of their physical origin, and a recognition of this relationship will be an easy and legitimate mnemonic device.

Thus in Equation 13, page 108, one may read each term as the value in diopters of a lens or a pencil. One recognizes the f 's as typical of focal distances, and the r as a radius, but f' and f'' are also radii, and their magnitudes measure the flatness of the incident and refracted waves; $\frac{1}{f}$ is the curvature of a wave-surface, and μ'' is the coefficient of slowness for wave-travel in the medium thus indexed, while $\mu'' - \mu'$ is the lag of the wave as it passes from one medium to another; and so on until the whole physical theory is read from the necessary geometrical relations.

Refraction and Reflection.—With *Snell's law* for a stepping-stone we now pass to the geometrical consideration of *refraction* and *reflection*. This

law for nearly a hundred years was the expression merely of the results of experience in the observation of refracted light. It is now generalized and applied to both reflection and refraction. Its consistency with the *wave theory of light* may be seen as follows:

When a wave-surface whose section may be represented by ab (Fig. 59) passes through d , the surface separating one medium from another in which

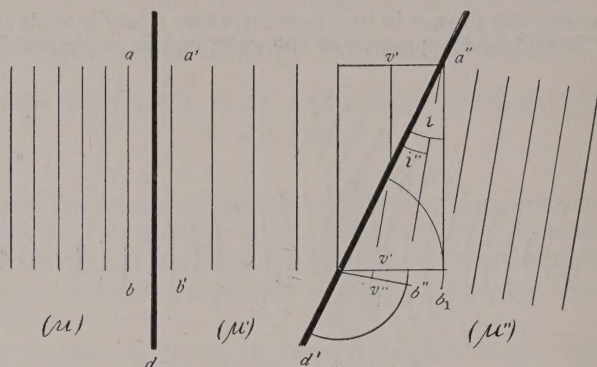


FIG. 59.—Showing that a wave-surface is not changed in its direction by passing through (d) an optical surface parallel to it, however the character of the medium may change at that surface, but that when the optical surface (d') is inclined to the wave-surface, the latter must experience a change in its direction dependent on its change of velocity in passing from one medium into the other.

for any reason whatever light makes its way at a different rate of speed, if the wave-surface immediately before its passage is parallel to the surface separating the two media, it will be parallel to it immediately after its passage, because at no time have the circumstances governing its speed differed along the whole line of the wave-front, the change having taken place everywhere at the same instant. The length of section is immaterial so that it be straight. Its straightness as a measurable quantity is the arc divided by the radius, so whatever the curve for a section *as small as you please*, the above statement is practically true, neither end of the wave gains on the other and it continues to advance in a straight line.

If the wave enters a retarding medium whose surface, d' , is not parallel to its own, instead of making its way as it otherwise would to the position a'' , b_1 , the spread of the light-disturbance from particle to particle has covered, say, a smaller area in the new medium than in the old, and the limit of its advance is along the common tangent of the circles whose radii are proportional to the time since they began to form in the new medium. Since the line v' represents the velocity of propagation in the medium μ' and v'' in the medium μ'' , the desired relations are easily established. Each is perpendicular to its wave front and is consequently a *radius* or *ray*; a'' , b_1 shows the place to which the wave would have advanced had the character of the medium not changed at d' , and a'' , b'' shows the place to which it really has advanced during the same interval of time. Each forms the side of a right-angled triangle whose hypotenuse is the separating surface, and whose respective bases are corresponding sections of wave-surface, and form with the surface of separation the angles i' and i'' . One of these angles is the *angle of incidence*; the other is the *angle of refraction*. Hence the sine of the angle of incidence is to the sine of the angle of refraction as the velocity at incidence is to the velocity after refraction, or, as usually stated,

$$\frac{\sin i'}{\sin i''} = \frac{v'}{v''}. \quad (1)$$

In practice it is easy to locate the centers from which the waves come and to which they go, and easy to locate the center of the optical surface; connecting these centers, p' , p'' , or p''' and n with the point of incidence a (Fig. 60), gives us the three radii, each of course perpendicular to the surface to which it belongs, and consequently mutually inclined to each other as are those surfaces.

Through the relations of these radii the law was discovered, through them it is most easily proved, and through them it is most frequently stated, angles of incidence, reflection, and refraction being defined as angles made by the incident, reflected, or refracted ray (perpendicular) with the radius of the optical surface.

The ability to transfer the attention from surfaces to rays, and to replace velocities by their reciprocals, is a great geometrical advantage, though it gives a show of artificiality to the whole theory of optical instruments as far as we have occasion to pursue it.

If μ , however accented, is taken to represent $\frac{1}{v}$, Equation 1 may be written

$$\sin i'\mu' = \sin i''\mu'', \quad (2)$$

and Equation 2 is **Snell's law**.

As here used, μ' , μ'' , etc. represent the time needed for light to travel unit distance in the medium with which each is connected; they might be called coefficients of slowness or coefficients of sine magnitude; they are, in fact, called *indices of refraction*.

The time needed for light to spread unit distance in ether—or in air, which is very nearly the same—is the standard of measurement, and is assumed to be 1. The actual value in seconds for ether, for air, or for other media is of no special import to us here; we need only the relative magnitudes, which are known or easily obtained, and are represented by μ appropriately accented. When μ is equal to 1, it is often omitted from a product as a matter of brevity and convenience. In all the formulæ here used it will be written for the sake of symmetry and clearness.

With this much of physical explanation and the law of sines as the rule of the road, we may proceed to speak of *rays* and *foci* as of *pencils* and *points*, hoping that their true significance will not be forgotten, and believing that the little effort that is necessary to identify physical with geometrical relationships will more than pay for itself as a guard against error and as a mnemonic aid.

We shall use the word *refraction* in its most general sense, including refraction and reflection. If exceptions to this usage occur, they will be noted.

The first general problem that presents itself in the study of image-forming optical instruments is this: Given waves of circular section, what will be their curve in either medium after incidence on the spherical surface which separates it from another of different index?

The problem may be solved by the aid of Fig. 60, *A*, in which waves at a h would converge upon the point p' , except that the optical surface changes their curvature, giving them a center at p'' . In this particular case n , h , p' , μ' , μ'' are known, and p'' is sought, but the solution desired should enable us to determine the position of any one of the quantities when the others are given, h being the point where the optical surface meets the line connecting its center with that of the incident wave.

At h the incident wave and the optical surface have a common tangent, and there is no change in the direction of the wave or of its radius; consequently, the center of the two waves will be on a line with the center of the optical surface. At any other point of incidence the law of sines applied to the two known radii will indicate the third, and its cross with the axis at p'' will be approximately the center of wave curvature. The solution is as follows:

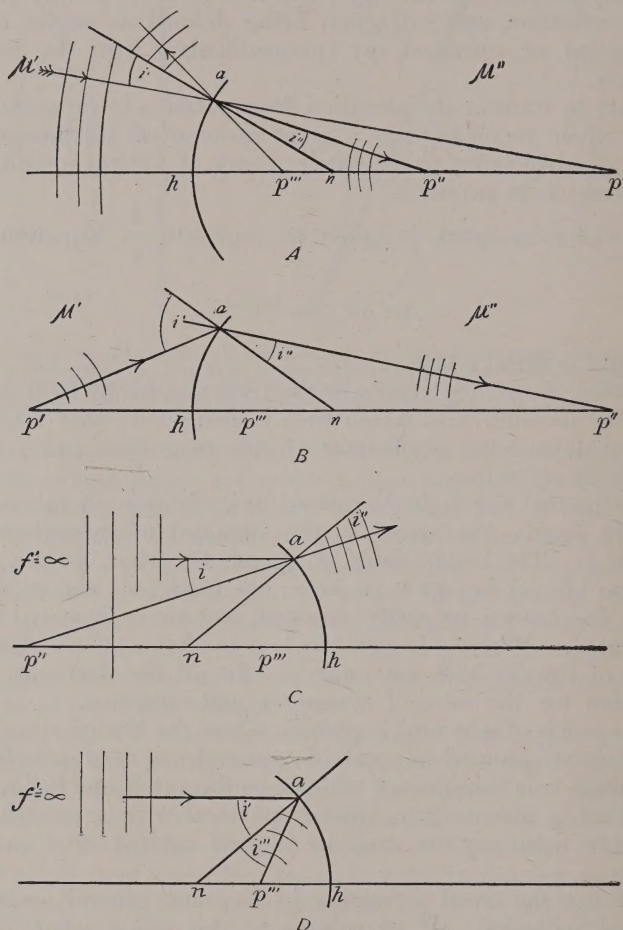


FIG. 60.—Typical cases of refraction and reflection, showing the relative positions as expressed by Snell's law to be the same for rays and normals as for the surfaces to which they belong. At h the waves are parallel to the optical surface; a is any point common to optical and wave-surfaces; p' is the center of the incident wave, p'' of the refracted, and p''' of the reflected wave. The values of radii, curvatures, and focal distances are ordinarily considered positive when the centers to which they appertain lie to the right of h ; in (A) they are all positive.

For the convenience of a one-letter notation draw Fig. 61 identical with Fig. 60, but represent the radius of the refracting surface by r , the distance of any point p from the center of the refracting surface by g appropriately accented, the distance of any point p from a by e , also appropriately accented, and distances from h by f . Then in Fig. 61 will be seen one triangle whose sides are r , e' , and g' , and whose vertex measures the angle of incidence, and another triangle whose sides are r , e'' , and g'' , and whose vertex is the angle of refraction. The angle between r and g may be called δ .

From the well-known property of triangles come these two equations :

$$\frac{\sin i'}{\sin \delta} = \frac{g'}{e'}. \quad (3)$$

$$\frac{\sin i''}{\sin \delta} = \frac{g''}{e''}. \quad (4)$$

Dividing 3 by 4 to eliminate δ ,

$$\frac{\sin i'}{\sin i''} = \frac{g'e''}{e'g''}. \quad (5)$$

By Snell's law, Eq. 2,

$$\frac{\sin i'}{\sin i''} = \frac{\mu''}{\mu'}. \quad (6)$$

Therefore,

$$\frac{\mu''}{\mu'} = \frac{g'e''}{g''e'} \quad \text{or} \quad \mu''g''e' = \mu'g'e''. \quad (7)$$

It should be noticed here that when the point a (Fig. 61) is placed very near to h the pole of the optical surface, e is nearly equal in value to f , and at the limit, when a and h become identical, any e is exactly equal to the corresponding f . The value of f at the instant when a and h coincide is the value that gives accurately the curvature of the wave at h . If the wave is circular in section, p'' determined for one point on its surface is determined for all. When the refracted wave has not a circular section, it is usual in practice either to shut

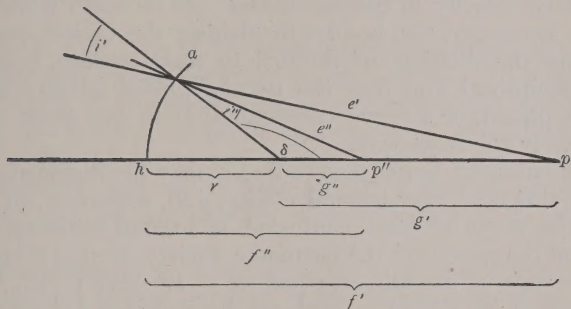


FIG. 61.—A one-letter notation for case (A) Fig. 60.

off that portion of its surface which departs appreciably from a uniform curve, and assumes that all the rays cross at the limiting position of p'' , or to name for the focal point that position of p'' which is nearest to the greatest number of rays at once. Some information may be obtained concerning the curve of the wave by substituting for e' and e'' in Eq. 8 the value which each possesses by virtue of its being opposite to the angle δ in the triangle to which it belongs; thus :

$$e'^2 = g'^2 + r^2 - 2g'r \cos \delta. \quad (8)$$

$$e''^2 = g''^2 + r^2 - 2g''r \cos \delta. \quad (9)$$

Squaring 7 and substituting the value e from 9,

$$\mu'^2 g'^2 (g'^2 + r^2 - 2g'r \cos \delta) = \mu'^2 g'^2 (g''^2 + r^2 - 2g''r \cos \delta). \quad (10)$$

It is not necessary to ask here the full significance of this formula, but only to remark that when g' is equal to $\left(\frac{\mu''}{\mu'}\right)^2 g''$, δ disappears from the equation, and consequently the refracted wave has a circular section. One such position may be found for p' on either side of r . The distance from any position of p'' to the limiting position when $a h = 0$ is the aberration for the

angle δ (longitudinal spherical aberration), and there is no aberration for such values of g' or g'' as cause δ to disappear.

As will be readily appreciated, any irregularity in the curvature of the refracted wave interferes with the point-to-point correspondence of the image to its object. The optical surfaces of most instruments are spherical, and many circumstances conspire to limit our use of these surfaces to that part which is so near the axis as to be practically without aberration, or to have only so much aberration as may be ignored or eliminated by compensatory errors; so in all first approximations p'' in its limiting position is taken as the focus conjugate to p' ; and since the e 's and the f 's are in this position identical, Eq. 7 may be written thus:

$$\frac{\mu''}{\mu'} = \frac{g'f''}{g''f'}, \quad \text{or} \quad \frac{\mu''}{\mu'} = \frac{f''}{f'} \div \frac{g''}{g'}. \quad (11)$$

Designating these segments by their terminal points, as in Fig. 60, the nature of the relation sought becomes apparent:

$$\frac{\mu''}{\mu'} = \frac{hp'}{p'n} \div \frac{hp''}{p''n}. \quad (12)$$

In ($h n p'p''$) we have an anharmonic range in which the two foci are conjugate to the center and the pole of the optical surface, and the cross ratio is the ratio of wave velocity in the two media. It is worth while to study into this a little if necessary, for, besides furnishing the easiest possible method of remembering the relations of the foci to their surface, it shows that the relations are reciprocal, and that the two foci, being given a surface of any curve, may be placed, or a curve corresponding to any place may be determined in precisely the same way.

Any combination of lenses and mirrors may be replaced by an equivalent surface: this is of very general utility, and, moreover, in the theory of thin pencils the circle of least confusion is located between the first and second focus of the pencil by the harmonic variety of this relation, the ratio being, as in the case of the mirror, equal to -1 . (See p. 127.)

Again, when g in Eq. 11 is replaced by its equal ($f-r$), we have the following:

$$\frac{\mu''}{\mu'} = \frac{(f'-r)f''}{f''-rf'}, \quad \text{which, when reduced, as it easily}$$

can be, gives the most important formula in this part of the book:

$$\frac{\mu''}{f''} - \frac{\mu'}{f'} = \frac{\mu'' - \mu'}{r}. \quad (13)$$

In as brief a treatise on geometrical optics as this must be, Eq. 13 may be considered an epitome of all that has gone before and a key to all that follows. It should be committed to memory and associated with Fig. 60, *A*, until each is a "word-sign" for the other. It should never be written in any other form until it has become so familiar to the eye that from any side an error of transcription would be discovered at a glance. It is general in its application for the focal distances of axial pencils for a surface of any circular curvature, plus or minus, between any media of whatever index. It might just as well have been deduced from any of the special cases pictured in Fig. 60, and the preceding applies and may be read equally well in connection with any one of these cases. p''' is used in this figure to indicate the position which p'' assumes when $\mu'' = -\mu'$; that is, in all cases of reflection. Fig. 60, *A*, was chosen as the type by which all may be classed and remembered, because in it all the curvatures, all the focal distances, and other magnitudes are positive quantities; and if Eq. 13 is remembered as belonging to the case where all the quantities are plus, no confusion need arise

in interpreting apparent anomalies of sign when a numerical equation of this form presents itself.

The discussion of Eq. 13 is much more simple than its derivation. If the optical surface is a plane, r becomes infinite and the last member vanishes, and consequently $\frac{\mu''}{f''} = \frac{\mu'}{f'}$ or $\frac{\mu'}{\mu''} = \frac{f'}{f''}$, which must be construed to mean that the conjugate foci of a plane refracting surface are on the same side of the surface and at distances whose ratio is the same as the indices for the two media. If any value represented by f' , f'' , or r has a minus sign, it of course represents a distance to the left of h . If f' or f'' represents an infinite value, the inference is that the wave surface is perfectly flat, that the rays are parallel.

Only in one case can μ' and μ'' be replaced by quantities having different signs. That μ' should equal $-\mu''$ would indicate a position of the wave that physical conditions can only account for by the supposition that it is a reflected wave—that is, turned back into the medium whence it came—and consequently travelling with the same velocity as before. Therefore the numerical value of μ'' must be the same as μ' . And it can be stated in this connection that when the indices differ in sign their numerical values do not differ, and $\left(\frac{\mu'}{\mu''}\right) = -1$. This only happens in cases of reflection.

It is not only unnecessary, but it is confusing, to make any distinction between problems of reflection and refraction other than what is indicated by the signs of the refractive indices.

The simplicity and generality of the conditions is such that the laws, the methods, the formulæ, and their interpretations are the same for katoptrics as for dioptrics.

Katoptrics is that part of the science of optics that deals with the phenomena of reflection, especially from regular surfaces like mirrors.

Dioptrics treats of the phenomena of refraction, and with the definitions we dismiss the distinction, except in such degree as it is shown by the signs of the indices. Eq. 13 is the open sesame to all of Optics that we require. When the quantities that are represented by μ' and μ'' are of unlike sign, they are equal and we are dealing with reflection. All other cases are refractive.

The inverse situation is covered by the rule which tells us to treat all mirrors as optical surfaces between media whose indices are 1 and -1 .

Cardinal Points, four in number, may be named in connection with a single optical surface (Fig. 62). They are n , the center of the surface, h , the

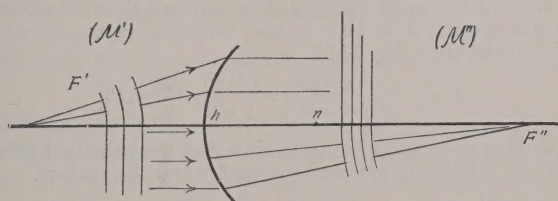


FIG. 62.—Above, the first principal focus is a radiant, and rays become parallel in (μ') . Below, rays parallel in (μ'') converge in (μ'') to the second principal focus.

principal point, F' , the first principal focus, and F'' , the second principal focus.

The Center.—Since concentric circles are parallel, the wave whose center of curvature before incidence is n will have n for a center after incidence—*i. e.* the ray that passes through n is unrefracted.

It will be seen hereafter that the relative size of object and image is the ratio of their respective distances from n ; that they approach n together; that each is inverted in passing through n ; and that when they meet at n the size of one, in terms of the other, is numerically equal to the ratio of the velocities of the light waves by which

the respective images are formed. It will be seen also that the center n is to the optical surface what the two nodal points n' and n'' are to the lens or the optical system.

The principal point h is the point where the optical surface is pierced by the line connecting its center with the radiant.

Object and image approach h together. At h they are equal and congruent (see page 112), and to h of the optical surface correspond the two principal points, h' and h'' , of the system.

The principal foci, F' and F'' , are the same for the surface as for the system.

The first principal focus, F' , is the center of those waves which after incidence become plane. In other words, F' is the cross of rays that are made parallel by incidence on the optical surface.

The second principal focus is the center of those waves that before incidence on the surface were parallel; or it may be stated thus: Rays previously parallel cross after incidence at the last principal focus.

These foci are found by giving to the variables of Eq. 13 such values as will impose the required conditions.

To find F' , substitute ∞ for f'' in Eq. 13 and solve for f' . This is because the center of a plane wave or the focus of a parallel pencil is at infinity. If $f'' = \infty$, $\frac{1}{f''} = 0$, and so disappears from the expression, and we have

$$f' = -\frac{\mu' r}{\mu'' - \mu'} = F', \quad (14)$$

the necessary result of the condition imposed.

The second principal focus, F'' , is found in the same way, for when $f' = \infty$, $\frac{1}{f'} = 0$, and

$$f'' = \frac{\mu'' r}{\mu'' - \mu'} = F''. \quad (15)$$

To apply this, suppose light from air is incident on a convex glass surface whose radius is one-fifth meter (.20 m). Replacing μ' by 1, the index for air, μ'' by 1.54, the index for glass, and r by .20, Eq. 15 gives

$$F'' = \frac{1.54 \times .20}{1.54 - 1} = \frac{.308}{.54} = .57.$$

If the surface had been concave, as in Fig. 60 (C), r would have been equal to $-.20$, and F'' would have had the same value, with a contrary sign to indicate that it was on the left of h . If the surface is to be a mirror, the same equations are used, and μ' is put equal to $-\mu''$; thus from Eq. 14:

$$F' = -\frac{-\mu'' .20}{\mu'' - (-\mu'')} = \frac{\mu'' .20}{2\mu''} = \frac{.20}{2} = .10.$$

For F'' one obtains the same result, showing that the principal focus for either side of a reflecting surface is halfway between the center and the surface.

When F' and F'' , the principal foci, are known, a very simple formula may be obtained for placing the conjugate of any other given focal point; thus, multiplying Eq. 13 by r and then dividing each numerator by $\mu'' - \mu'$, it becomes

$$\frac{\mu'' r}{\mu'' - \mu'} - \frac{\mu' r}{\mu'' - \mu'} = 1.$$

Replacing each numerator by the values obtained from Eqs. 14 and 15, we have

$$\frac{F''}{f''} - \frac{F'}{f'} = 1. \quad (16)$$

Free from fractions and subtract $F'F''$ from each side :

$$\begin{aligned} F'f' + F'f'' - f'f'' - F'F'' &= F'F'' \\ (F'' - f'')(f' - F') &= -F'F'' \\ (F'' - f'') \text{ is } u'' \text{ (Fig. 63) and } (f' - F') \text{ is } u'. \end{aligned}$$

Changing the sign convention so that one accented quantity measures distances to the left and two accented quantities are measured toward the right,

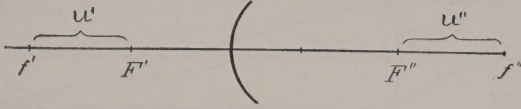


FIG. 63.—Showing the relation of conjugate foci to principal foci. Symmetrical notation about F' and F'' as origins.

we get a very convenient symmetrical notation for the relation of conjugate foci to principal foci :

$$u'u'' = F'F''. \quad (17)$$

For the relation given in Eq. 16 there is a very simple graphic solution. As the line k (Fig. 64) is turned on the point p whose rectangular co-ordinates are F' and F'' ,

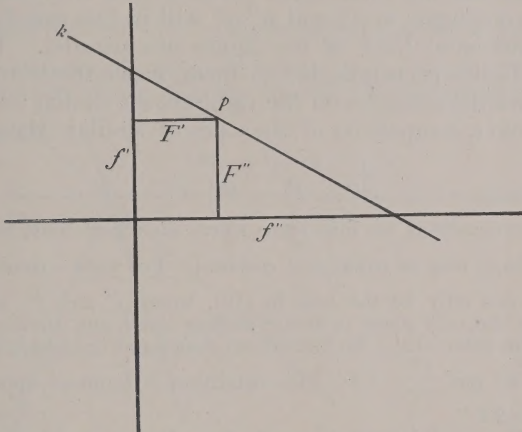


FIG. 64.—Graphic solution for Eq. 16.

the parts cut off from the axes are respectively equal to f' and f'' , due regard being had to sense.

Conjugate Images: Object and image are corresponding configurations of points. By this is meant that to each point in one configuration there corresponds a point in the other configuration whose relation to it and to some optical surface is that by which in the preceding paragraphs p' has been connected with p'' . The path of the light-wave being reversible, either configuration may in theory play the part of object to the other as image. Their distances from each other and from the cardinal points of the surface are determined by previous considerations. Their relative magnitudes are to be determined.

The magnification of an object by its image is ordinarily of two kinds, *longitudinal* and *transverse*. With the longitudinal, which may be obtained, for example, by comparing (Fig. 65) $q's'$ with $q''s''$, we will not here concern ourselves. The following is an easy geometrical determination of the transverse dimensions of object and image: Let the line $p'q'$ perpendicular

to the axis be represented by j' , its conjugate by $-j''$, minus because it is on the opposite side of the axis, and it is important to distinguish an inverted from an upright image. From the point p' let two lines be drawn, one parallel to the axis and one through F' , the first principal focus, and let them be continued till they meet the optical surface. As these lines are rays, their

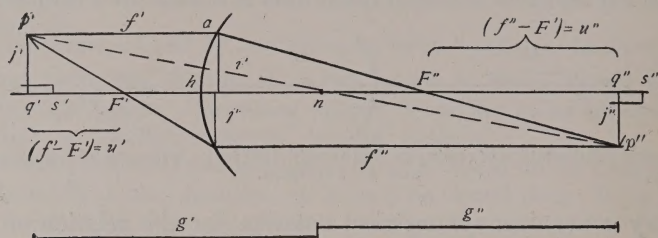


FIG. 65.—Image and object : magnification determined by properties of the principal foci (Eq. 18).

course after meeting the surface is determinate. That parallel to the axis will pass through the second principal focus F'' , and that from the first principal focus will be made parallel to the axis. Where these two refracted rays meet will be the focus conjugate to p' , and $p'' q''$ will in this case be $-j''$.

The three horizontal lines of the figure are parallel. The two j 's are within required limits perpendicular to them, hence the triangles on the left are all similar, and the triangles on the right are all similar; so we have these two equations from a comparison of the sides of similar triangles :

$$\frac{j'}{j''} = \frac{F' - f'}{F'} = \frac{F''}{F'' - f''} \quad (18)$$

From these two equations we may learn where an object must be placed in order that object and image may be equal and cosensual. For such a condition $\frac{j'}{j''}$ must be equal to 1. This can only be the case in (18), where f' and f'' are both equal to nothing; therefore the only place is at the surface itself, and there object and image meet and are of the same size. To find where object and image are equal in size and opposite in sense, we put $\frac{j'}{j''} = -1$. This condition is imposed upon (18), when $f' = 2 F'$ and when $f'' = 2 F''$.

By replacing F' and F'' by their equals from Equations 14 and 15, and letting f' and f'' each equal to r , Equation 18 reduces to $\frac{\mu'}{\mu''} = \frac{j'}{j''}$. This may be construed to mean, that when the two images meet, as they must, in the center of the optical surface, their dimensions are proportional to the velocity of light in the media to which they respectively correspond.

For refraction it will be seen, *e. g.*, that image and object are cosensual, but when, as in reflection, $\mu' = -\mu''$, $\frac{j'}{j''} = -1$, and therefore image and object are of opposite sense and equal in size.

In practice the center of a concave mirror may be found by placing a needle in its vicinity and moving it until its point is coincident with the point of its image. The cross-ratio (see page 108) by which the cardinal points of the mirror are connected with the conjugate foci being -1 , ($n h f' f''$) is an harmonic range, and, any three points being given, the fourth may be determined by the well-known formula :

$$\frac{2}{n h} = \frac{1}{f' h} + \frac{1}{f'' h} \quad (19)$$

The graphic solution is convenient, as it may be done with a pencil and straight-edge only. If three consecutive elements are given, as f' , h , f'' (Fig. 66), connect these three points by straight lines with any other point, a , not in a line with them. Through any point on the middle line draw two diagonals, as in the figure, and complete the

quadrilateral. Its fourth side will cut the axis at n , the point required. If one of the middle points of the range is sought, as h , connect the two contiguous elements with any point, a , as before. Cross the triangle thus formed by any line nc , put in the two

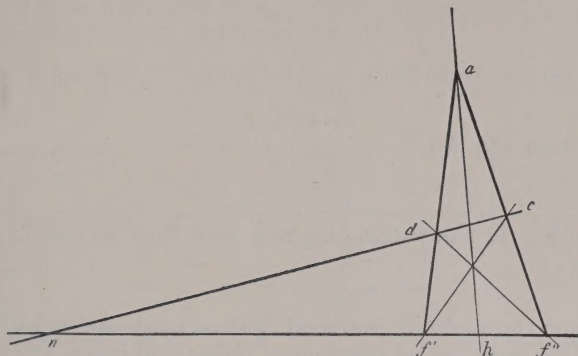


FIG. 66.—Graphic construction by which the following questions are answered: Given the surface of a mirror, what must its curvature be, or where must its center be in order to produce a picture of f' at f'' or of f'' at f' ? Given the center, where must the surface be? Given the mirror and the object, where will the image be? or the mirror and the image, where must the object be?

diagonals, and draw through their intersection the line ah ; h is the fourth harmonic sought.

An analogous construction serves for surface, lens, or system. Take three points, c , d , and e (Fig. 67), equally distant from the line an , and so placed that the distances cd

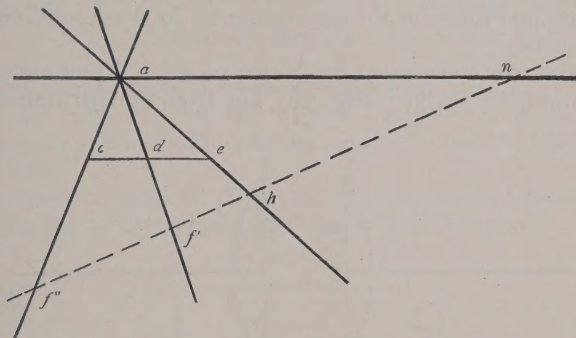


FIG. 67.—Graphic method for locating any one of the four cardinal points of an optical surface when the other three are known. Any axis may be placed across the pencil ($a c d e n$), so that any three points shall fall on any three of the lines. The point sought will be on the other line. It is only necessary in the construction to make $cd : ce = \mu' : \mu''$, and ce parallel to an .

and ce are proportional to the indices of the first and last media. From a through each of the other points draw a line. The axis of any optical surface may be placed across this pencil of four lines, so that three of the lines cross it at any three cardinal points. The fourth point is determined by the cross of the axis a and the fourth line. This drawing will answer too for all systems whose first and last media are in this ratio.

Before proceeding to show that other systems of more surfaces than one

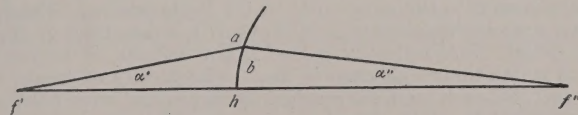


FIG. 68.— $\tan \alpha' : \tan \alpha'' = f' : f''$ (relative to "Helmholtz's formula").

may, if their centers are colinear, be treated much in the same way as single surfaces, it is necessary to prove *Helmholtz's formula* connecting the size

of each image with the inclination to the axis of any ray common to them all. Let f' a f'' (Fig. 68) be the ray between two images. Assuming the figure to be made up of two right-angle triangles,

$$\frac{a}{f'} = \tan \alpha \quad \frac{a}{f''} = \tan \alpha'';$$

therefore,

$$\frac{\tan \alpha'}{\tan \alpha''} = \frac{f''}{f'}. \quad (20)$$

As is evident from Fig. 65,

$$\frac{g'}{g''} = \frac{j'}{j''}. \quad (21)$$

Substituting in Eq. 11 the values obtained from Eqs. 20 and 21, we have the relation sought :

$$\mu' j' \tan \alpha' = \mu'' j'' \tan \alpha''. \quad (22)$$

Here we begin the study of **centered optical systems** by calling attention to the fact that the geometrical relations of object and image are such that distinction is often unnecessary ; that an object and its n images are frequently spoken of as $(n+1)$ images ; and that any image may be considered object or image at convenience.

The *position* and *size* of any image may of course be determined for any number of surfaces by proceeding step by step from the object to the final image through as many refractions and reflections as are necessary to attain it. This laborious method is avoided by the localization of cardinal points, which fulfil the same function for the system as do those previously described for the single surface.

Of focal points for the system this must be said : They are measured not from the first and last surface (Fig. 69), but from two **principal points** the

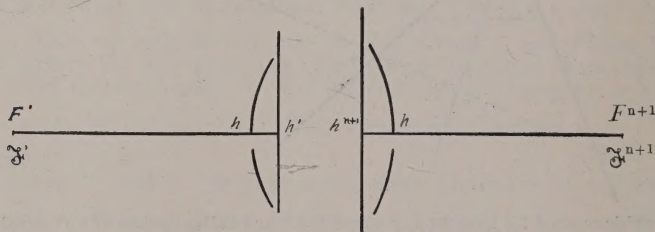


FIG. 69.—Foci of surfaces are measured from the surfaces, as F' , h . Foci of systems are measured from the principal points of the system, as $F'h'$.

“*first*” and the “*last*,” whose functions are described below, and whose positions and distances from their respective surfaces are designated by h' and h^{n+1} .

The “*second*” principal point, principal focus, principal plane, nodal point, and so on, are properly so named for a single surface, but for a system of surfaces to use the ordinal adjective thus is sometimes misleading. We shall use the term *last* principal point or $(n+1)$ th principal point, and so on, giving it the ordinal adjective and the number of primes that corresponds to the medium to which it appertains. This is not so much an innovation as a conscientious adhesion to the spirit and method of the notation and nomenclature in detail. Something is gained if the accents on letters serve to locate the phenomena to which their existence is due. The ability to locate other cardinal points—a set, in fact, for each medium reached by waves that were parallel at incidence on the system—may not be of any special importance, but it is of advantage to have characters systematically named and accented. It enables us to read our records aright and to locate easily the processes to which the characters refer.

The removal of the origin for the estimation of focal distances accounts for the appearance of h' and h'' in the denominators of Eqs. 23 and 24 (*infra*). The obscurity,

if any, vanishes when it is remembered that h and h''' as distances are, by convention, counted plus when measured into the system from the first and last surface respectively. F 's and Φ 's, the surface foci, are measured both right or both left, each from its surface, while the $\mathfrak{F}$'s, the foci for the system, are measured both in the same direction as the F 's and Φ 's. This is the reason why in Eq. 23 F' has been replaced by $(\mathfrak{F}' - h')$, while in Eq. 24, Φ''' has been replaced by $(\mathfrak{F}''' - h''')$

We may now proceed to the consideration of three media separated by

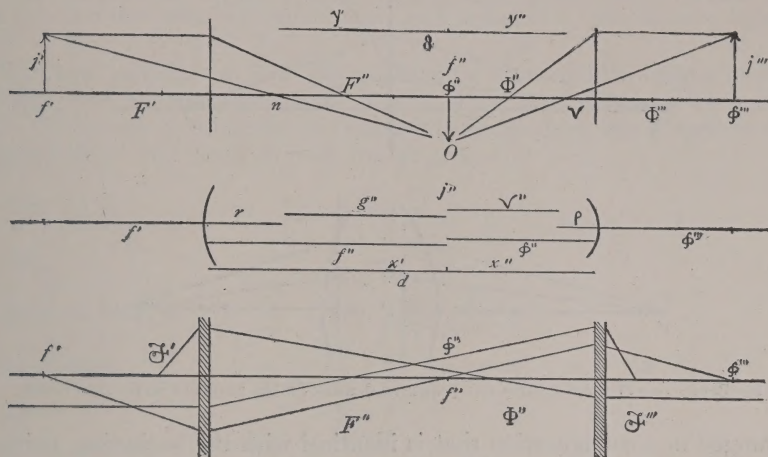


FIG. 70.—Combined systems of optical surfaces.

two surfaces. In this system are three images (Fig. 70), j' , j'' , and j''' , each corresponding to light distribution in the similarly accented medium, j'' serving as image to j' by the first surface, and as object to the image j''' by the second surface.

The first principal focus of the system is the focus conjugate by the F surface (Fig. 71) to the first principal focus of the Φ surface. Changing the

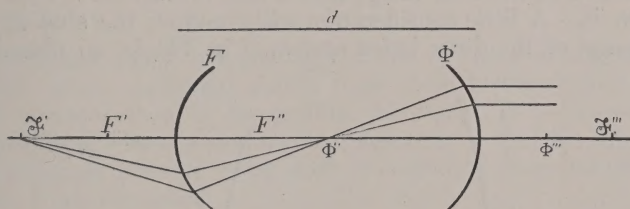


FIG. 71.—“The first principal focus of the system is the focus conjugate by the F surface to the first principal focus of the ϕ surface.”

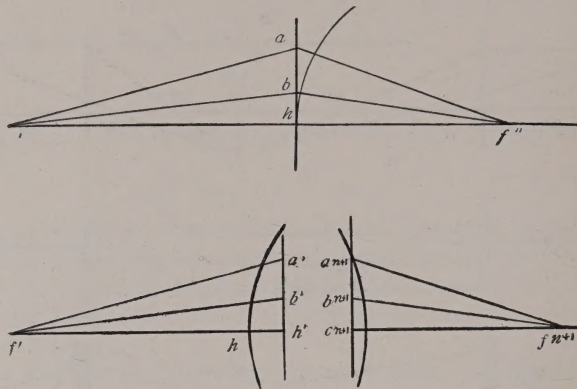
surface of reference, thus from one surface to another, demands, of course, that ϕ be replaced by $(\phi - d)$. d , being the distance between the two surfaces $(\mathfrak{F}' - h')$, is obtained from Eq. 13 by the following substitution, and, being the only unknown quantity, its value is immediately forthcoming:

$$\frac{\mu'''}{\phi'' - d} - \frac{\mu''}{\mathfrak{F}' - h'} = \frac{\mu'' - \mu'}{r}. \quad (23)$$

By the same method is obtained

$$\frac{\mu'''}{\mathfrak{F}''' - h'''} - \frac{\mu''}{F'' - d} = \frac{\mu''' - \mu''}{\rho}. \quad (24)$$

Principal Planes.—There are definite reasons for replacing the one principal point on the pole of the single surface by the two points, h' and h'' , not necessarily on any surface. We may imagine a plane through each cardinal point perpendicular to the axis and designated by the name of the point. On the *principal plane*, which is tangent to and within required limits is coincident with the single surface (Fig. 72), the end points of incident rays



FIGS. 72 and 73.—Principal points and planes as defined for the surface and for the system.

are arranged in a configuration that is identical with the beginning points of refracted or reflected rays; and it will be remembered that conjugate images approach this plane together until their corresponding points are united each to each and the two images become identical. No such single plane can be placed in any system of optical surfaces, but two planes perpendicular to the axis may always be found such that the configuration of end points a' b' h' (Fig. 73) of incident rays on one surface is congruent with a^{n+1} , b^{n+1} , and c^{n+1} , the beginning points of reflected or refracted rays in the last or $(n+1)$ th medium, such also that when the first image moves toward one of these planes and disappears in it, the final image moves also toward the second plane and disappears in it. A little consideration will convince the student that if J , the *middle image* of the three index system (Fig. 74), be so placed that it as

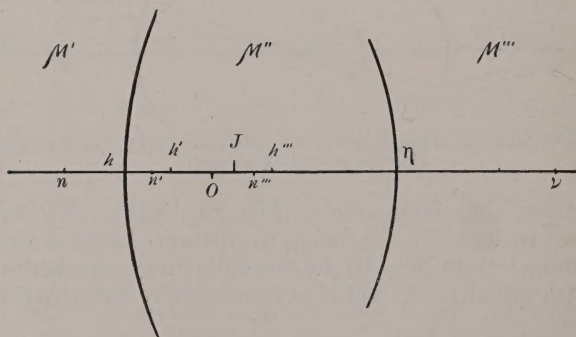


FIG. 74.—The cardinal points of a three-index system: Above, h and η , first and last surfaces; h' and h'' , first and last principal points; J , middle image. Below, r and n , first and last centers; n' and n'' , first and last nodal points; O , optical center.

an object produces two images (one by each surface) equal in size and cosensual, these two images will lie in planes which answer the above description. We

shall call this middle image J . From these planes along the axis conjugate foci of the system are measured.

Whatever transformations take place within the system are comparatively unimportant if only we may receive light emergent from one plane apparently unchanged since its entrance at the other. If also these planes are so related that the object approaches one as its image approaches the other, until in size and sense alike each disappears in its plane, then the two principal planes are quite fit to replace the single plane of the single surface, and Fig. 73, which we use here to illustrate the system, becomes exactly what Fig. 72 would become if pulled apart and separated by the distance between h' and h''' .

We now proceed to find the position of this middle image, indicating principal foci as usual by capital letters, other focal distances by small letters. Of course the distance of the *middle image* from the F surface will be indicated by f'' , its distance from the Φ surface by ϕ'' .

$$\begin{aligned} \text{From Eq. 18,} & \quad \left. \begin{aligned} \frac{j'}{j''} &= \frac{F''}{F'' - f''} \\ \frac{j'''}{j''} &= \frac{\Phi''}{\Phi'' - \phi''} \end{aligned} \right\} \quad (25) \\ \text{Also,} & \\ \text{Divide 25 by 26, and} & \quad \frac{j'}{j'''} = \frac{F''\Phi'' - F''\phi''}{F''\Phi'' - \Phi''f''}. \end{aligned}$$

$$\begin{aligned} \text{By condition,} & \quad \frac{j'}{j'''} = 1; \quad \text{therefore} \quad F''\phi'' = \Phi''f'', \\ \text{and} & \quad \frac{\Phi''}{F''} = \frac{\phi''}{f''} \quad (26) \end{aligned}$$

Thus it is seen that the middle image will have in the two surfaces conjugates that are equal and cosensual if it divides the middle medium into parts proportional to the principal foci appertaining thereto. If d represents the distance between the surfaces and J the place of the middle image, Jh will be equal to $f'' = \frac{d F''}{F'' + \Phi''}$. The conjugate focal distance Jh' may be found by substituting this value for f'' in Eq. 13.

In like manner Eq. 13 applied to the Φ surface will give the value of ϕ''' for h''' from that of $\phi'' = \frac{d \Phi''}{F'' + \Phi''}$.

It is hardly necessary to repeat that h' and h''' used as magnitudes define the distances of the principal points from their surfaces: they are usually considered positive when in the middle medium. It is not uncommon to give to an optical system a symmetrical notation, so that the direction $F' F''$ $h' h''$ are considered positive when each is measured from its own principal plane away from the other.

Optical Center.—It remains for us to determine what point or points, if any, may be found along the axis of the system having properties like those of the centers of single surfaces. There is, generally speaking, no point through which as through a center light will pass without change of direction. Only in the special case where the centers of the surfaces are coincident can this happen. One may assume, however, that somewhere is a point so situated that light passing through it will be equally and oppositely refracted at the two surfaces. In this case the first and final paths, though not necessarily identical, must be parallel.

The optical center is the name by which this point is known, and to determine its place we make use of Equation 22. By it the linear dimensions of O are connected with those of its first and last image; thus,

$$\mu' j' \tan \alpha' = \mu'' O \tan \alpha'' = \mu''' j''' \tan \alpha''' \quad (27)$$

We may drop out the middle term of this equation, and as the condition imposed is that α' is equal to α''' , the other tangents also disappear, giving

$$\mu'j' = \mu'''j''', \quad (28)$$

the condition to which we must conform in locating the three points. By the usual notation we use g to measure distances from the first center, and γ those from the second, and remember that—

$$\mu'F'' = \mu''F', \text{ and } \mu''' \Phi'' = \mu'' \Phi'''; \quad (29)$$

which may be easily proved.

Referring to Fig. 70, where the distribution along the axis of the cardinal points of the two surfaces is shown in its relation to O and its two images, we have two expressions for the relative size of each pair :

$$\frac{j'}{O} = \frac{g'}{g'' - F'} = \frac{F''}{g'' - F'}. \quad (30)$$

$$\frac{j'''}{O} = \frac{\gamma'''}{\gamma'' - \Phi'''} = \frac{\Phi''}{\gamma'' - \Phi'''}. \quad (31)$$

Dropping out the middle terms and multiplying Eq. 30 by μ' and Eq. 31 by μ''' ,

$$\left. \begin{aligned} \frac{\mu'j'}{O} &= \frac{\mu'F''}{g'' - F'} \\ \frac{\mu'''j'''}{O} &= \frac{\mu''' \Phi''}{\gamma'' - \Phi'''} \end{aligned} \right\} \quad (32)$$

The two right-hand members are equal by Eq. 28. Expressing the equality of the two left-hand members after substituting the numerators from Eq. 29 and dividing by μ'' ,

$$\frac{F'}{g'' - F'} = \frac{\Phi'''}{\gamma'' - \Phi'''}. \quad (33)$$

By composition and alternation,

$$\frac{F'}{\Phi'''} = \frac{g''}{\gamma''}. \quad (34)$$

Calling δ the distance between r and ρ , we find here again, for the optical center as for the middle image, we must divide a distance into parts propor-

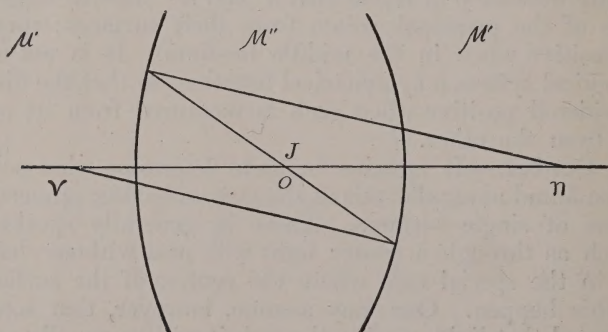


FIG. 75.—The optical center of a lens. The cross of the axis with a line connecting the surface ends of two parallel radii is the optical center.

tional to the principal foci of the two surfaces, but this time we must use the principal foci for rays that are parallel in the middle medium, whereas before we used the principal foci for rays that were parallel outside the middle medium.

In a three-index system the *optical center*, and in the lens, where the first and last media are the same, both *middle image* and optical center can be located geometrically, as in Fig. 75. The surface ends of any two parallel radii are connected by a straight line; its cross with the axis is the optical center of the lens.

The image of the optical center in each surface gives the nodal point corresponding to that surface; it may be found by Eq. 13 as above, remembering that

$$\frac{\delta F'}{F' + \phi'''} = g'', \quad \text{and} \quad \frac{\delta \phi'''}{F' + \phi'''} = \gamma'', \quad (35)$$

and that

$$g'' + r = f'' \quad \text{and} \quad \gamma'' + \rho = \phi''.$$

These two points are called **nodal points**, and transformations of waves and rays incident to the passage of light from one of these points to the other may in many cases be ignored, for we know that what goes into the system as if directed to n' will come out unchanged in direction as if from n''' . So here, again, we have, as in the case of the principal points, lost space, and the geometrical constructions which give graphic solutions with single sur-

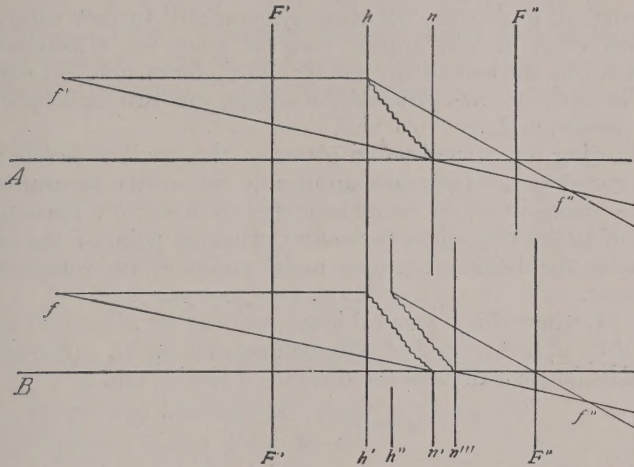


FIG. 76.—Construction for finding the conjugate to any radiant when the cardinal points are known. A is the axis of an optical surface; B , the axis of a system of surfaces. Cardinal planes are indicated by the usual letters. Cardinal points are where those planes intersect the axes. To find the conjugate of any radiant f' in the surface A , draw two rays, one parallel to the axis, one through the center of the surface. The former after refraction must pass through the principal focus; therefore its path is determined. The direction of the latter is unchanged by refraction. Its cross with the first ray is the focus f'' conjugate to f' . For a system the method is the same, except that for incident rays the surface and center are replaced by the first principal plane and first nodal point. Refracted rays are drawn from the last principal plane and last nodal point. It will be noticed that the second picture is identical with the first, except that all the lines have parted either at the surface or the center, and the diagram has been lengthened by the break an amount equal to $n' n'''$.

faces may be used equally well for systems; but every picture thus formed will be broken in two, some of its lines parting at the principal plane, some at the center. The two halves being separated by translation parallel to the axis, there will result a similar construction, except that the surface h takes on a finite thickness equal to $h' h'''$, and the center n instead of being a point is stretched out into a line, reaching from n' to n''' , and equal in length to $h' h'''$.

It is hardly possible in an article as short as this must be to include rigid demonstrations of everything necessary to its usefulness. Little, so far, has been omitted which was necessary to show both geometrical and functional

relations existing between the cardinal points of the optical system and the center, the pole, and the two foci of the single surface.

The student who desires to pursue the matter in the same thorough manner must be referred to Helmholtz for whatever of proof is omitted from the remaining pages.

By a continuation of the methods used above it can be proved that when the principal points are located for any system of two surfaces, and when the principal foci of the system are measured from these points; that when the nodal points are placed, and $\mathcal{G}'$, $\mathcal{G}'''$, g' , and g''' be used as above to indicate distances from them; and when, as in Eq. 17, u' and u'' are used to measure distances away from the center, with the principal foci as origins,—then not only Eq. 13, but also Eqs. 17 and 18, apply equally well to the system as to the surface, if only allowance be made for the lost space between the principal planes and between nodal points.

This fact is of great practical utility, as it gives no restriction at all in cases where the thickness of the lens is small as compared with its focal length. In most of the cases where spectacles are used the thickness of the glass may be ignored. When we add to this statement the extension which is warranted by fact that not only may surfaces be compounded into systems without change of properties, but these systems still further compounded, the one with the other, it will appear that for every set of surfaces, however many in number, an equivalent set of eight points may be determined as follows: The *optical center*, the *middle image*, the two *principal points*, the two *nodal points*, and the two *foci*.

The following formulæ give the places of the *cardinal points* where three media are concerned. They are applicable to media separated either by surfaces or systems, if only it be remembered to measure d from the last principal point of the first medium to the first principal point of the last medium, and to measure the distance between nodal points of the component systems in like manner.

In Fig. 74, where d is $h\eta$ and δ is $n\nu$, we may let x' and x'' represent the sections of d by J , and y' and y'' the sections of δ by O . (See also Fig. 70.)

The *middle image* J divides the distance d into x' and x'' :

$$\left. \begin{aligned} Jh &= x' = \frac{F''d}{F'' + \Phi''} \\ J\eta &= x'' = \frac{\Phi''d}{F'' + \Phi''} \end{aligned} \right\} \quad (36)$$

The *optical center* divides the distance δ into y' and y'' :

$$\left. \begin{aligned} On &= y' = \frac{F'\delta}{F' + \Phi'} = \frac{\mu' F'' \delta}{\mu'' (F'' + \Phi'')} \\ Ov &= y'' = \frac{\Phi''' \delta}{F''' + \Phi'''} = \frac{\mu''' \Phi'' \delta}{\mu'' (F'' + \Phi'')} \end{aligned} \right\} \quad (37)$$

From Fig. 75 it is easily proved that δ and d are similarly divided by O . We may therefore substitute d for δ , h for n , and η for ν in Equations 37, and so obtain the formulæ for the position of the optical center as measured from the two surfaces.

Principal Points.— h' and h''' as linear magnitudes are positive when measured from h and η , the extremes of d toward the middle medium:

$$\left. \begin{aligned} h' &= \frac{x' F''}{F'' - x'} = \frac{F'' d}{F'' + \Phi'' - d} \\ h''' &= \frac{x'' \Phi''}{\Phi'' - x''} = \frac{\Phi'' d}{F'' + \Phi'' - d} \end{aligned} \right\} \quad (38)$$

Principal Foci.— $\mathfrak{F}'$ and $\mathfrak{F}'''$ are considered positive when each principal point comes between its focus and the other principal point :

$$\left. \begin{aligned} \mathfrak{F}' &= \frac{F'\Phi''}{F'' + \Phi'' - d}, \\ \mathfrak{F}''' &= \frac{F''\Phi'''}{F'' + \Phi''' - d}. \end{aligned} \right\} \quad (39)$$

Nodal points, n' and n''' , are measured inward from the extremities of d :

$$\left. \begin{aligned} n' &= h' + \mathfrak{F}''' - \mathfrak{F}' = \frac{F'd + F''\Phi''' - F'\Phi''}{F'' + \Phi'' - d}, \\ n''' &= h''' + \mathfrak{F}' - \mathfrak{F}''' = \frac{\Phi'''d + F'\Phi'' - F''\Phi'''}{F'' + \Phi''' - d}. \end{aligned} \right\} \quad (40)$$

From these last equations, by the substitution of the values of the F 's and the Φ 's, as obtained by Eqs. 14 and 15, are deduced the simplest expressions for the cardinal points of any system. They flow from the above equations without complication or difficulty, and are obtained by the ordinary processes of elimination. Expressed in terms of $\mu'\mu''\mu'''r$ and ρ , they reduce to vulgar fractions having

$$\mu''(\mu''' - \mu'')r + \mu''(\mu'' - \mu')\rho - (\mu''' - \mu'')(\mu'' - \mu')d = N, \quad (41)$$

for a common denominator. This term, being constant for the system, may be calculated once for all, and so is abbreviated to N , there being no physical significance here intended. It is merely an abbreviation borrowed from Helmholtz.

These are the values :

$$\mathfrak{F}' = \frac{\mu'\mu''r\rho}{N}, \quad \mathfrak{F}''' = \frac{\mu''\mu'''r\rho}{N}. \quad (42)$$

$$h' = \frac{\mu'(\mu'' - \mu''')r d}{N}, \quad h''' = \frac{\mu'''(\mu' - \mu'')\rho d}{N}. \quad (43)$$

$$\left. \begin{aligned} n' &= \frac{\mu'(\mu'' - \mu''')r d + \mu''(\mu''' - \mu')r\rho}{N}, \\ n''' &= \frac{\mu'''(\mu' - \mu'')\rho d + \mu''(\mu' - \mu''')r\rho}{N}. \end{aligned} \right\} \quad (44)$$

$$\left. \begin{aligned} H &= \mathfrak{F}'' - \mathfrak{F}' = \mathfrak{F}' - \mathfrak{F}''' = d - h' - h''' = d - n' - n''' \\ &= \frac{(\mu'' - \mu')(\mu''' - \mu'')(r - \rho - d)}{N}. \end{aligned} \right\} \quad (45)$$

Eqs. 39 to 45 may be used without restriction.

These general formulæ may be much simplified by the imposing of certain conditions which often occur in practice. Thus, if the middle medium is very thin, d may be considered equal to 0. In that case H is also equal to 0, and h, h', J, h''' , and η all coincide ; so the last term in N disappears, and our system is practically described by the two values of $\mathfrak{F}'$ and $\mathfrak{F}'''$. The first two terms only of their denominators being left, we write in full, as follows :

$$\left. \begin{aligned} \mathfrak{F}' &= \frac{\mu'r\rho}{(\mu''' - \mu'')r + (\mu'' - \mu')\rho}, \\ \mathfrak{F}''' &= \frac{\mu''r\rho}{(\mu''' - \mu'')r + (\mu'' - \mu')\rho}. \end{aligned} \right\} \quad (46)$$

If both radii are now supposed alike, the middle medium drops out of the account,

$$\mathfrak{F}' = \frac{\mu'r}{\mu''' - \mu'}, \quad \mathfrak{F}''' = \frac{\mu''r}{\mu''' - \mu'}. \quad (47)$$

and we have a single optical surface between the first and third medium—a condition realized in the passage of light through the cornea and aqueous.

A still more important condition that may be imposed on a system of two surfaces is that the first and last media shall have the same index. This gives the lens proper.

The Lens.—It would seem the part of wisdom to confine the term “lens” to such combinations, and to use the word “system” for others. In this way a distinction is made which is in keeping with the derivation of the word and with ordinary mechanical constructions, and which is continually in evidence through the simplicity of the resulting formulæ, while a lens that is used as a window between two different media is such only in name, and the name so used is definitive only of a triviality. We shall use the word “lens” only for two-index systems. The crystalline lens of the eye is not excluded from this category, as the aqueous and vitreous are of the same refractive power.

Reducing Eq. 41 to 45 by letting $\mu''' = \mu'$, we have the formulæ characteristic of lenses:

$$\mathfrak{F}' = \mathfrak{F}''' = \frac{\mu' \mu'' r \rho}{\mu'' (\mu'' - \mu') (\rho - r) + (\mu'' - \mu')^2 d}. \quad (48)$$

$$\left. \begin{aligned} h' &= n' = \frac{\mu' d r}{(\mu'' - \mu') d + \mu'' (\rho - r)}, \\ h''' &= n''' = - \frac{\mu' d \rho}{(\mu'' - \mu') d + \mu'' (\rho - r)}. \end{aligned} \right\} \quad (49)$$

$$H = d \frac{(\mu'' - \mu') (d + \rho - r)}{(\mu'' - \mu') d + \mu'' (\rho - r)}. \quad (50)$$

Fig. 77, illustrative of the preceding paragraphs, shows the disposition along the axis of the cardinal points of several optical systems. *a* is a single optical surface, and to it corresponds the aphakic eye and the schematic eye of Listing. *b* is the general case of two surfaces separating three media, all of different indices. In this the nodal points and the principal points are not identical. *c* is a true lens as described above, in form resembling the crystalline. In it, as in *defg*, other lenses, principal points, and nodal points coincide, and it may be noted that, assuming $\mu'' > \mu'$ and *d* less than $r + \rho$, positive lenses are thicker in the middle.

Double convex and double concave lenses have their principal points between the curved surfaces. In plano-convex and plano-concave lenses *h'*, *h'''*, and *J* all come together on the curved surface. In the meniscus they pass out of the substance of the lens and arrange themselves in the medium farthest from the centers of curvature.

j corresponds to the human eye, *k* to the eye with a spectacle lens before it.

The continuity of a series of systems is seen by looking, for example, at system *b*, and noting that the point $\mathfrak{F}'''$ in the relevant formulæ is such a function of μ''' and ρ that one may be increased as the other is decreased without altering the place of $\mathfrak{F}'''$; so that wherever in a system of three media $\mathfrak{F}'''$ happens to be placed by making the compensatory changes in ρ and μ''' , μ''' may be brought to be equal to μ'' without altering the places of the principal foci. In this way, without changing the disposition of the foci, *h'''* may be varied until it is equal to *r*, in which case *h'* will be equal to nothing. In other words, the single surface may be treated as a system in which the third index of refraction is equal to the second, and whose second surface has an infinite curvature, and whose center and surface are both coincident with the center of the first surface. Such a substitution of values may always be made in the use of Eqs. 47 to 50, where one of the component systems is a single surface.

The Diopter.—Consistent with any scheme that measures the direction of light-propagation as positive, the curvature of the wave is considered positive when its center is in front of it, for its radius must be then positive, and so,

whether mirror, refracting surface, or system, its strength as an optical factor is estimated by the curve of the wave, the convergence of the rays that may be produced by it. The unit which is now universally and almost exclusively used in the estimation of the strength of lenses is the *dioptr*, suggested by Nagel and named by Monoyer. It is to the credit of ophthalmologists that in their optical work inches are being fast forgotten. Lenses are thus described by giving to each the reciprocal of its focal length in meters, and placing before this number the sign + or - to denote whether it has a real or virtual focus for parallel rays. The convenience of this method is its chief recommendation, as combinations of lenses are subject to computation by simple addition in an all but universal standard of measurement, instead of requiring pencil and paper computations in terms that are none too rapidly becoming archaic.

The *focal length* of a lens whose dioptric number is given is of course the reciprocal of that number in meters, or one hundred times that reciprocal in centimeters.

In comparing the two systems it may be said of one that it designates the lenses by their focal lengths in inches, the other gives to a lens its additive value in dioptr. To reduce accurately from either system to the other, one divides 39.37 by the number of the lens. A sufficient approximation for all test-case examples is to use 40 as the dividend. Thus a glass of 8-inch focus is equal to 5 dioptr. A three-dioptr lens has a focal distance of one-third of a meter—that is, 33 c.m.—or, if its old number in inches is desired, divide 40 by 3. It is approximately No. 13; accurately, it is 13.123, unless the method of calculation has proved superior to the method of its original manufacture and measurement, which for ordinary spectacle lenses is quite likely to be the case.

For all thin lenses the distance between the principal planes may be ignored, and the equations that have been used for surfaces may be used without restriction; and in their use they admit of such simplification as comes from putting $\mathfrak{F}' = \mathfrak{F}''' = \mathfrak{F}' = \mathfrak{F}'''$. There are but three cardinal points to such a lens. The *middle image*, the *optical center*, the two *nodal points*, and the two *principal points* are all united in a single point halfway between the two principal foci.

The *strength* or *power* of a lens is the convergence that it can produce in parallel rays. It is also the curvature it can give to a plane wave that passes through it; it

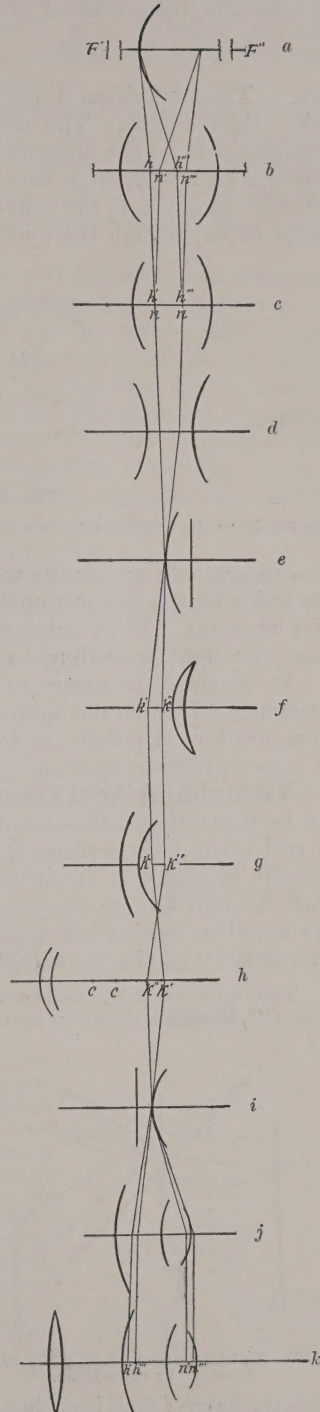


FIG. 77.—Showing the relative positions of the principal points and nodal points for different systems of surfaces.

is also the reciprocal of its focal distance. Either one of these definitions implies the other. Whichever way it is defined, $\frac{1}{\mathfrak{F}}$ is its measure. This definition must be modified for a single surface or a system other than a lens. The dioptric strength of such a system is consistently considered to be the measure of the curvature in air or vacuum which it will impress on a wave that was flat before reaching it. Some such convention must be adopted, as the convergence produced is greater on the side of the lesser index, though the system is the same (Fig. 78). With this limitation

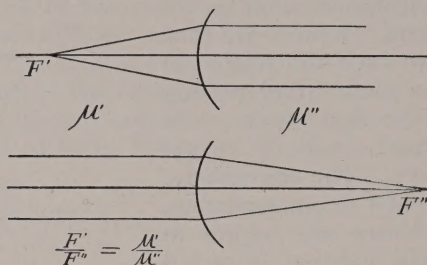


FIG. 78.—For a single surface the convergence produced in parallel rays is greater on the side of the lesser index.

we can evaluate systems as well as lenses in diopters, and the value will be the index of the last medium divided by the length of the principal focus in that medium. With this convention the dioptric value of a system is the same for light travelling in either direction.

It is hardly necessary to define further the word “focus,” or the word “conjugate,” which has been used so often to signify that two points or two configurations of points are associated as object and image through the agency of some surface or system.

Virtual and Real Images.—But the distinction of *virtual* and *real* has not been mentioned thus far in relation to foci and images. A focus or image is real when it is a place from which light really emanates or to which it actually attains. It is virtual when the physical conditions that it represents, though having no real existence, are such that they would account for the reactions taking place at some other point if there were no break in the homogeneity of the intervening medium.

Thus we see in Fig. 79 light from any point of j' falls on the screen k' as if coming from j''' , though no light-waves or rays enter the medium behind the reflecting surface.

Again, were the surface a refracting surface, the light would fall on the screen k'' as if coming from j'' , the virtual image of j' , though none of the waves that are disposed as if coming from j'' are in the medium in which j'' is placed. We may say, consistently with the notation of this article, that

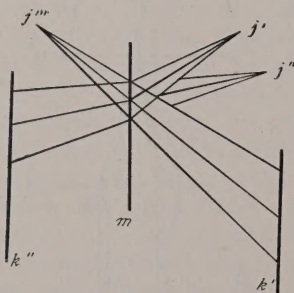


FIG. 79.—Virtual images of j'_3 , j'' by refractions, j''' by reflections.

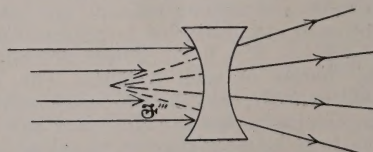


FIG. 80.—Virtual focus of concave lens.

when the image j finds itself in a medium whose accents are different from its own, the image is virtual. Examples of real images are seen in Figs. 72, 73, and 78. Fig. 80 shows a concave lens with its virtual focus at $\mathfrak{F}'''$.

We take note here that the general forms of the lenses given in Fig. 77 may be described by the following terms: *Double convex*, *double concave*, *plano-convex*, *plano-concave*, *concavo-convex*, or *convexo-concave*; the last variety when thinnest on the edges is called a *meniscus*.

Applying Eqs. 48 to 50 to obtain the characteristic properties of this group, one easily proves that the principal points of the double convex and the double concave variety are between the two surfaces; that in the plano-lenses they are both united on the curved surface; that for the concavo-convex type they pass out of the substance of the lens on the side of the greater curvature.

It will be found also that when radii, surfaces, and indices are so arranged that the strength of the lens is negative—that is, when the lens has a virtual focus $\mathfrak{F}'''$ falling on the left in the figure and $\mathfrak{F}'$ on the right—then h' and h''' are also transposed, each being found between the other and its own principal focus. With one exception the lenses that are thickest in the middle are of positive focal length, and all positive lenses whose index is greater than that of the surrounding medium are thicker in the middle than at the edges. The one exception of a minus lens that is thinner at the edges occurs when r is greater than ρ , when d is greater than the distance between the centers, and when μ'' ($\rho - r$) is algebraically less than $(\mu'' - \mu')d$. Equation 49 will under such conditions give a minus value for $\mathfrak{F}'''$.

The *human eye*, as has been said, is a centered system of optical surfaces like that given in Fig. 77 (j). We copy here from Czapski's table of dimensions and constants, given for reference in his book on optical instruments, where figures collected from various sources by Helmholtz furnish what might be called a composite reproduction of the type, and where also are tabulated the results of careful measurements and calculations in a single case by Tscherning. Along the vertical line of Fig. 81 are the cardinal points and other points of interest as arranged on the axis of the eye. Between cornea and retina the spaces are correctly given on an enlarged scale of 2.5 to 1. All distances are in meters, so that when applied to use in the above formulæ the strength of a lens or system will be expressed in the diopter, the familiar unit of the test-case.

The cases in which practice suggests or renders useful the application of the above formulæ are not infrequent. We mention only two: One a case of *axial myopia* in which a supposition that the dioptric system of the eye has remained the same, but the retina has been displaced backward an amount which is easily calculated from the strength of the glass needed to give distinct distant vision. Suppose the size of the retinal image is required for the corrected eye. The correcting lens is usually made as thin as possible; hence its optical center and all the cardinal points except the two foci are at its geometrical center. F'' is minus, and, measured along the axis, F' is plus; d is the distance of the correcting lens from the cornea added to 0.0017532, the distance of the cornea in front of h' of the eye. Both foci of the emmetropic eye may be obtained from the table, and thus the figures are all obtainable for getting principal points and nodal points for the complete system through the application of formulæ 36 to 41.

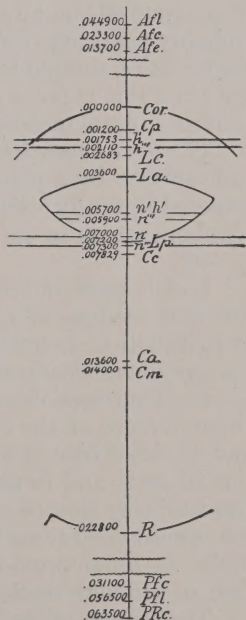


FIG. 81.—The cardinal points of the human eye, measured from the cornea. From cornea to retina, enlarged to a scale of 2.5:1.

Another interesting case occurs where the lens has been removed and a strong plus glass is worn. The nodal points of the glass may be calculated without difficulty, or, if used for reading, a plano-convex, with the flat side in front, will be acceptable to the patient, and its nodal points are on the convex surface.

The surface of the cornea is the principal point of the eye, and its curvature read from the ophthalmometer locates its center, which is the nodal point for the aphakic eye, or this center may be assumed to be like the average and supplied from Fig. 81.

It can be hardly thought necessary to guide the student farther, as he has now all the points of the component systems which are required to give the cardinal points of the equivalent or resultant system, and these being found, the magnification is forthcoming by Eq. 18 or Eq. 20.

Astigmatic Surfaces and Pencils.—We pass now to a very brief consideration of astigmatic surfaces and pencils. We have thus far assumed that the optical surfaces were spherical—that is to say, surfaces of revolution about their common axis, and whose principal sections were circular.

It happens that such is not always the case. Imperfections of the cornea or lens give for the surfaces of the eye itself imperfect approaches to sphericity; and even if that were not so, a displacement of any center or radiant focus from the axis of the system produces the same change in the transmitted or reflected pencil that would result from imperfect curvature of the surface.

For the small pencils with which we deal there is only one form of astigmatism. It is that which would be given to a pencil of light by the optical action of a toric surface. A *sphere* is the surface developed by the revolution of a circle about one of its diameters. A *torus* is developed by the revolution of a circle about any line that is in the same plane, but not a diameter. Roughly speaking, when the axial line is a cord the torus is shaped like an apple with a dimple in its blossom end equal to that in its stem end. When the axial line is not a cord, the torus is like an anchor ring. When the line is at an infinite distance from the circle the toric surface is a cylinder.

The *toric lenses* in use are supposed to be such as might be sliced from a toric surface by a plane parallel to its axis of development. Such a lens is centered optically when both its centers, the center of the circle and the center about which in its development the circle revolves, are on the axis of the system.

It will need but little consideration to convince the reader that in two different sections of such a surface the problems relative to the transmission of light will be exactly similar to those which we have just considered as true for any plane whatever of the spherical surface.

A plane section of the toric surface may be taken perpendicular to the circumference of the developing circle, or coincident with that circumference, and in either case it will be a circular section. In one case it will be the section of least, and in the other the section of greatest, curvature, with foci correspondingly shorter and longer than in other sections; and in each case may the optical conditions be described and determined by the same laws and formulæ as those previously considered for a spherical surface, which is a surface of circular section.

The section of the toric surface through its two centers, both of which we suppose to be on the axis of our optical system, may take place through a meridian not coincident with the section of greatest or least curvature, and then consecutive rays from any axial point will not be reunited by this surface on the axis, but near it. The result is that an axial pencil directly incident on such a surface has the characteristics that are portrayed by Fig. 82, showing the general form of the pencil from Aubert, and the distribution of

its component rays as in a diagram by Edward Jackson from Norris and Oliver's *System of Diseases of the Eye*.

The point along the axis that can be most satisfactorily utilized as a focal point is at F_0 in the figure. It is the place where the rays are collected into the smallest bundle. It is called "the circle of least confusion," and its place between F_1 and F_2 divides that distance in such ratio that it is a fourth

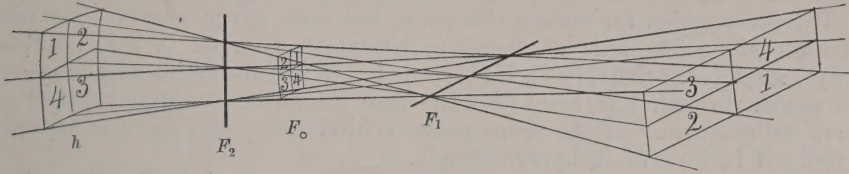


FIG. 82.—Showing the distribution of rays and focal lines in an astigmatic pencil ($h F_0 F_2 F_1 = -1$).

harmonic to F_1 and F_2 . Consequently, it is determined by the same formulæ and constructions that are used to locate the conjugate foci in a spherical mirror (see pp. 108 and 113).

Astigmatism is usually an anomaly and not a desideratum. It is measured and discussed in terms of the diopter, which have proved equally useful whether applied to pencils or lenses.

The amount of astigmatism is the strength of a lens which under ordinary optical conditions would change the convergence of the meridian of least to that of greatest curvature, or *vice versa*. The correcting lens must be essentially a toric, and one also whose focal anomaly is exactly equal and opposite to that of the pencil to be corrected. For simplicity the cylinder is usually chosen, and, having only one finite focus, it is designated by the dioptric value of the correction required.

In correcting the anomalies of refraction and accommodation it is not in general possible to use a simple lens, either cylinder or sphere. One gives the cylinder necessary to make either of the extreme foci coincident with the other, and then adds whatever of spherical correction is required. The particular combination of cylinder and sphere that is used is more a matter of commercial than of physiological interest.

The astigmatism that has been described as produced by a toric lens is the only kind that has been successfully and systematically corrected. It is for "thin pencils" the only kind that exists, and for pencils as large as may enter the pupil it is the only kind that merits attention, *aberration* being so well known by its own name as to be considered, if at all, under a separate head.

The classification of astigmatism into "simple," "compound," "myopic," "hyperopic," and so on may have its clinical advantages, but it seems to the writer to be of very doubtful propriety. We deal only with one kind of astigmatism. It may have its existence in a myopic eye, a paper-weight, or in the glass door of a Gothic house, but a nomenclature that takes cognizance of such facts is confusing to the novice unless he clearly understands that the astigmatism and its method of correction is the same in every case.

For those who find it convenient to classify astigmatism by its associated anomalies it may be stated that when the retina of the eye at rest falls behind the posterior focal line, the condition is what is called "*compound myopic astigmatism*;" when it falls on the posterior focal line, it is called "*simple myopic astigmatism*;" when it falls between the two focal lines, it is called "*mixed astigmatism*."

When the retina passes through the first focal line it is called "*simple hyperopic astigmatism*," and when in front of both focal lines the anomaly is said to be "*compound hyperopic astigmatism*" (see also p. 227). This cumbersome and useless attempt at precision, as it is usually taught, merely serves to conceal the fact that there is a point on the axis between the first and second focal lines through which the retina must pass to obtain the best image compatible with that particular degree of astigmatism.

The construction for finding this point has been given above. The distribution along the axis of the four letters in Fig. 82 is $hF_2 : hF_1 = -F_0F_2 : F_0F_1$, or, briefly, $(hF_0F_2F_1) = -1$. When the retina of the eye at rest passes through this point (F_0), the case should be considered simply as one of astigmatism. If the retina passes behind this point, there is myopia as well; if in front of it, hypermetropia.

The glasses found in most trial cases for the correction of astigmatism are cylinders in pairs, both plus and minus, quarter numbers to 2.50, and half numbers to 6. The spherical lenses are usually in quarter numbers to 2.50, half numbers to 7, whole numbers to 14, and then increasing two diopters at a step to 20 or 22, a pair each of both kinds, plus and minus, the cylinders usually plano-cylinders, the sphericals double convex or double concave.

Optic Axis ; Line of Vision ; Line of Fixation ; Line of Sight.—

We have spoken of the eye as a centered system, and such it is in type. Its principal points, its nodal points, its center of motion, as well as the cardinal points of the lens, are usually all on one line or nearly so. This line is called the *optic axis*. It is approximately the axis of symmetry for the whole organ. It is sometimes the case that the macula, the center of the most acute perceptive power, is directly in this line, but oftener it is not. When the optic axis passes through the macula, it is the *line of vision* as well, meaning by the line of vision or the *line of sight* the line on which the object must be placed in order that the visual act should be most advantageously performed. Under these circumstances also the optic axis is the *line of fixation*, for it is the line passing through the center of motion and indicative of the eye's position or aim.

An excentric position of the macula lutea is so common as to be the rule rather than the exception. It is usually toward the outer side of the optic axis. Consequently, the line of vision is no longer coincident with that axis, but crosses it with a slight "fault" at the nodal points, and the line of fixation connecting the center of motion of the eye with the object on which it is trained has now a position which differs from the optic axis almost as much as the line of vision.

The angle OMA (Fig. 83) is taken as the measure of this lack of symmetry due to the excentricity of the macula. It is called *the angle gamma*, γ . It is reckoned as plus when the optic axis falls outside of the visual axis.

Another peculiarity of construction must be considered in connection with the form and position of the cornea.

It is convenient, and in some measure consistent with existing conditions, to look upon the cornea as ellipsoidal rather than spherical in its contour. Its horizontal section if the curve were completed would occupy a position in the average emmetropic eye something like that pictured in Fig. 84. Here it is seen that the corneal major axis does not coincide either with the visual axis or the optic axis. The lack of symmetry thus pictured is usually measured by the angle which the major axis of the cornea makes with the visual axis. This angle is known as α , *the angle alpha*, and is reckoned plus when the

visual axis pierces the cornea on its nasal side. In high myopia the angle a is often negative (see also p. 96).

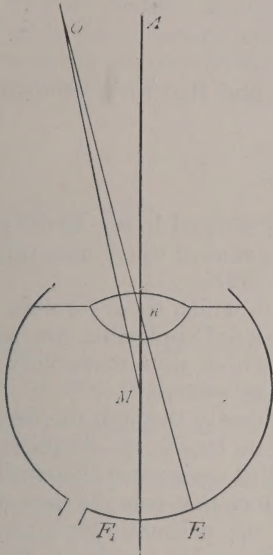


FIG. 83.— $OMA =$ The angle gamma.

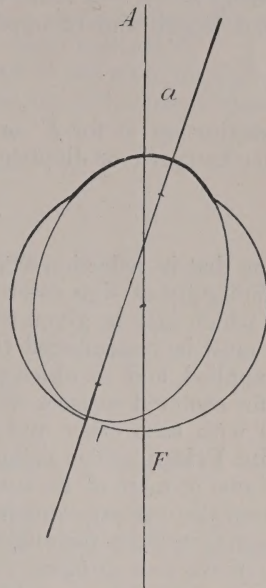


FIG. 84.—The angle alpha.

Mirrors.—In the eye itself are no plane surfaces, and no surfaces whose chief function is comparable to that of the mirror; but such surfaces must be considered as being intrinsic parts of many instruments. The mirror-like action of the dioptric surfaces of the eye is made use of in various methods of investigation.

A mirror being only a special case of single optical surface where $\mu' = -\mu''$, it may be most satisfactorily discussed in connection with previous studies by making the substitution of μ' for $-\mu''$ in the general formulæ 13 and 18.

Substituting and reducing, we have

$$\frac{1}{f'''} + \frac{1}{f'} = \frac{2}{r}. \quad (51)$$

As has been previously mentioned, this formula is suggestive of the harmonic relation for which a construction has already been given (Figs. 66 and 67). Whichever side of the surface is used, the principal focus is halfway between the center and the surface. It is found from Eq. 13 in the usual way.

It is evident from the formula or from the graphic construction that image and object are always on the same side of the principal focus; also that they are always separated by the surface or the center, never by both; also, wherever the object, the image that is on the same side of the principal focus as the reflecting surface is a virtual image.

The relation between the size of object and image is precisely the same as for dioptric surfaces, and may be determined either by Eq. 18 or 21.

We have but one more present application for Eq. 13, and that is for the special case where the surface, either dioptric or katoptric, is plane. In such case $r = \infty$, the second member disappears, and

$$\frac{\mu'''}{f'''} = \frac{\mu'}{f'}. \quad (52)$$

which may be construed as saying that the foci conjugate to a plane optical surface vary as their respective indices. Make this a reflecting surface again by putting $\mu'' = -\mu'$, and we find that foci conjugate to a plane mirror are of equal length and of opposite sense; thus:

$$\frac{1}{f''} = -\frac{1}{f'} \quad (53)$$

Substituting ∞ for F' or F'' in Eq. 18, we find that for plane surfaces, whether katoptric or dioptric,

$$\frac{j'}{j''} = \pm 1, \quad (54)$$

showing that in reflection or refraction the image is equal in size to the object. The ambiguity of sign enters the equation on account of the double interpretation which may be given to the expression for infinity.

It must be remembered that the conditions to which these formulæ have been applied, and to which alone they are considered applicable, are such as exist for centered surfaces and pencils of light whose rays make very small angles with each other and with the axis of the system.

The Prism.—The *prism* enters a system optically through the decentering of one or more of its surfaces. The prismatic lens in its simplicity differs from the ordinary lens in no other way, and the prismatic element in the lens is measured by the angle between the two lines that contain the cardinal points of the two surfaces. To qualities which the prismatic glass possesses by virtue of its curved surfaces must be added those that are due to the non-coincidence of the two axes, and these are best studied in the case of the plane prism. The action of a prismatic lens as used in ophthalmology is the added action of the simple lens and the plane prism. The plane prism is made up of two plane optical surfaces inclined to each other at an angle less than 180° . The first and third media are usually alike. These conditions cannot be considered analogous to any previously discussed, as on one or both planes the pencil is oblique; neither is it possible to look upon both planes

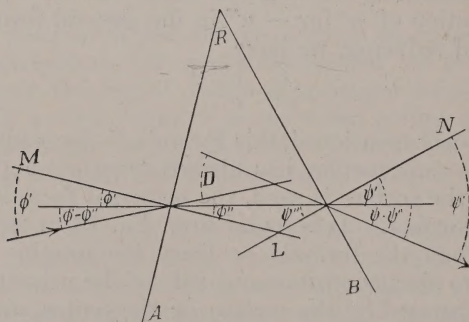


FIG. 85.—Refraction of light in the principal section of a plane prism.

as centered on any finite axis. Consequently, we have to begin again with the law of Snell, and we confine ourselves to refraction in a principal section.

The *apex* or *edge* of the prism is the intersection of the two planes forming its sides or faces. A *principal section* is a section of the prism by a plane perpendicular to the edge. A *base-apex line* is the line of intersection of either side with a *principal section*. From Snell's law we know that a ray of light which before incidence is confined to a *plane of principal section* will pass

through the prism without passing out of that plane. Such plane is pictured in Fig. 85, where angles made with the normals to the first surface are designated by ϕ , those made with the second surface by ψ , and where the primes show in what medium the light-ray making the angle is situated.

If R is the refracting angle of the prism and D the total angular deviation caused in any ray passing through the prism, the following relations are easily established:

$$D = \phi' - \phi'' + \psi' - \psi'' \quad (55)$$

$$R = \phi'' + \psi'' \quad (56)$$

$$D = \phi + \psi - R \quad (57)$$

Applying Eq. 2 to the angles in question, gives

$$\mu' \sin \phi' = \mu'' \sin \phi'' \quad (58)$$

$$\psi' = R + D - \phi' \quad (59)$$

$$\psi'' = R - \phi'' \quad (60)$$

and $\mu' \sin \{(R + D) - \phi'\} = \mu'' \sin R - \phi'' \quad (61)$

Hence, by easy trigonometry,

$$\sin (R + D) \cos \phi' - \cos (R + D) \sin \phi' = \frac{\mu''}{\mu'} \left\{ \sin R \cos \phi'' - \cos R \sin \phi'' \right\} \quad (62)$$

When the prisms are thin, as in most spectacle lenses, the angles R and $R + D$ may be substituted for their sines, and 1 for their cosines, giving

$$D = R \left\{ \frac{\mu''}{\mu'} \frac{\cos \phi''}{\cos \phi'} - 1 \right\}; \quad (63)$$

and this is still further simplified in

$$D = (\mu'' - \mu') R, \quad (64)$$

by limiting the angle of incidence to one so small that

$$\frac{\cos \phi'}{\cos \psi'} = 1.$$

When the light-ray passes symmetrically through the prism, as in Fig. 86, $\frac{R}{2}$ may be substituted for ϕ'' and ϕ'' , giving

$$\frac{D}{2} = \sin^{-1} \left(\frac{\mu''}{\mu'} \sin \frac{R}{2} \right) - \frac{R}{2}, \quad (65)$$

which is useful, because it expresses the action of the prism on light which

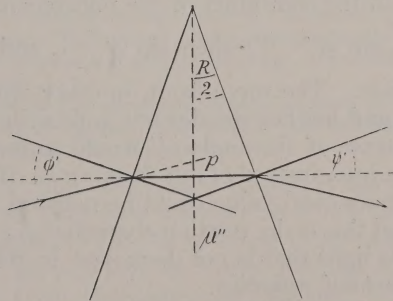


FIG. 86.—Refraction at position of minimum deviation.

passes through in its position of *minimum deviation*, a term which defines itself.

The deviation at position of *perpendicular incidence* or *perpendicular exit* is given by

$$D = \sin^{-1}\left(\frac{\mu''}{\mu'} \sin R\right) - R. \quad (66)$$

A simple transposition of 65 gives

$$\frac{\mu''}{\mu'} = \frac{\sin \frac{R+D}{2}}{\frac{R}{2}}, \quad (67)$$

the formula for getting the index of refraction from the deviation and refracting angle.

Total Reflection.—There is one special condition that comes to our notice generally in connection with reflection and refraction at plane surfaces. We may take as illustration Fig. 87, and ask guidance of Snell's law

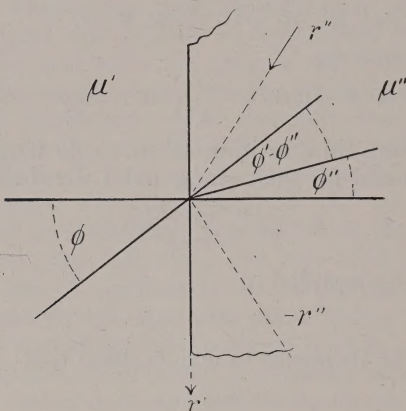


FIG. 87.—Concerning total reflection.

when the wave whose normal r , incident from the denser medium (μ''), makes with the limiting surface an angle whose sine, multiplied by $\frac{\mu''}{\mu'}$, is greater than 1. The path that Snell's law would seem to indicate for the refracted wave would be an impossible path, for there is no angle whose sine is greater than 1. Under such conditions refraction does not take place.

There is no break in the continuity of the phenomena, for when the angle ϕ'' is so great that $\frac{\mu''}{\mu'} \sin \phi'' = 1$; then $\sin \phi' = 1$, and the refracted ray, r' , is parallel to the surface. The wave-front, in other words, is perpendicular to the optical surface, and neither recedes nor approaches it.

A still greater increase of the angle ϕ'' would so increase ϕ' that its general direction would be into, instead of out from, (μ''). The angle would have a minus sine, but its numerical value could be nothing other than μ'' , since the medium is (μ''); and this is the relation characteristic of reflection. Under such conditions all the light that is not destroyed is reflected, and the phenomenon is known as *total reflection*.

The *prism* is of use in ophthalmology chiefly on account of its causing a deviation in the path of light, and thus furnishing an instrument which may be used either as cause of, or compensation for, slight anomalies of the position of the eye itself. The practical application to such purposes is given

elsewhere. In that application it is necessary to take cognizance of its value as used to cause deviation of light, and thus an apparent displacement of any object through it. The relation between the refracting angle and the deviation produced being such, prisms have until recently been described by their refracting angles as Pr. 1° , Pr. 2° , and so on. By Eq. 65 it will be seen that the deviation produced by any prism of ordinary glass, $D = (1.54 - 1) R$, is very nearly one-half the refracting angle of the prism; and since one-half a degree is about the smallest increment which ophthalmologists have found useful, the scale is a very convenient one, and in spite of criticisms is still much in use. Its only fault is that the numbers on the glasses do not correspond to the values for which they are used. To remedy this defect it has been proposed to number prisms by the angular deviation in degrees, replacing the degree-mark by a small d to avoid confusion, thus Pr. 1^d , Pr. 2^d . This is the *Deviation-angle System* of Jackson. The unit in this system is about double the value of the unit of the *Refracting-angle System*.

To obviate the necessity of making any material change in the size of the working unit, it was proposed to give to each prism the value of its angular deviation in terms of the radian, the only unit of angle that is recognized in works on analysis and mathematical philosophy. One one-hundredth of this, the radian angle, which, in accordance with "C. G. S." (Centimeter-Gramme-Second) nomenclature, is a *centrad*, is so near the unit of the Refracting-angle System as to be practically indistinguishable from it. This is the Centrad System of Dennett. The Refracting-angle System and the Centrad System so nearly coincide that for glass of any ordinary index some number between 0 and 35 will be identical for the two systems, and the others of the scale will be so near as to admit of interchange under ordinary circumstances. Centrads are prescribed thus: Pr. 1^∇ , Pr. 2^∇ .

The Prism-diopter Scale of Prentice does not differ much from the Centrad Scale, and does not differ appreciably from it in the numbers that are most used. It gives to every prism the value of the tangent of the deviation in hundredths of the radius. Centrads and the prism diopters are compared in Fig. 88.

The same fault may be found with the Prism-diopter Scale as with the Refracting-angle Scale—namely, the number on the glass is a transcendental function of the value for which the glass is used. Within the limits of common use the three scales are alike, and the choice is one of symbol and sentiment only. Prism diopters are described thus: Pr. 1^Δ , Pr. 2^Δ , and so on.

To Prentice is due also the suggested change of the $^\circ$ to d for the degree deviation, and to $^\Delta$ for the tangent deviation. The author has extended the symbolism to the centrad system by inverting the triangle for it.

There remains only the *Meter-angle System*, it having been suggested that the "Meter Angle" of Nagel be adopted as a unit for prism nomenclature.

The Meter Angle.—The *meter angle* is the angle made by the visual axis and the median plane when the eye is directed to a point in that plane one meter's distance from the center of rotation. The value of this angle depends, of course, on the interocular distance, which must needs be conventionalized if it is used for purposes of prism notation. An interocular distance of .06 makes the meter angle equal to 3^∇ . Though a little narrow for an adult, it is perhaps as good a distance as any to assume. The advantage

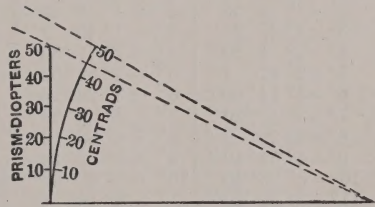


FIG. 88.—Showing the relation of prism-diopter to centrad.

of this unit is supposed to consist in this, that for any point of fixation convergence and accommodation are expressed in the same terms, the inclination of the axis to the median line being the same in meter angles as the accommodation in diopters. The writer is not aware that the meter angle is in actual use as a prism unit. Its relation to convergence may be seen in Fig. 89, and the following notation has been suggested: Pr. 1^m , Pr. 2^m .

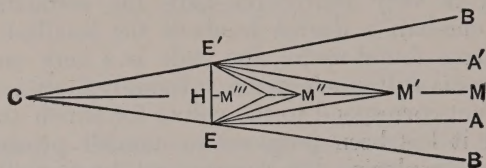


FIG. 89.—The meter angle.

Table I. gives the deviation in degrees corresponding to all the different systems of prism notation:

TABLE I.—*Showing the Value in Degrees of Deviation of Prism belonging to the Other Systems.*¹

Refracting angle.	Deviation.	Centrad.	Deviation.	Prism-di- opter.	Deviation.	Meter-an- gle.	Deviation.
Pr. $1^\circ = 0^\circ 32' 20''$		$1^\nabla = 0^\circ 34' 22''$		$1^\Delta = 0^\circ 34' 22'' +$		$1^m = 1^\circ 43' 6''$	
$2^\circ = 1^\circ 4' 50''$		$2^\nabla = 1^\circ 8' 45''$		$2^\Delta = 1^\circ 9'$		$2^m = 3^\circ 26' 12''$	
$3^\circ = 1^\circ 37' 20''$		$3^\nabla = 1^\circ 43' 7''$		$3^\Delta = 1^\circ 43'$		$3^m = 5^\circ 9' 18''$	
$4^\circ = 2^\circ 1' 20''$		$4^\nabla = 2^\circ 17' 30''$		$4^\Delta = 2^\circ 17'$		$4^m = 6^\circ 52' 24''$	
$5^\circ = 2^\circ 42' 8''$		$5^\nabla = 2^\circ 51' 53''$		$5^\Delta = 2^\circ 52'$		$5^m = 8^\circ 30' 5''$	
$6^\circ = 3^\circ 14' 50''$		$6^\nabla = 3^\circ 26' 15''$		$6^\Delta = 3^\circ 26'$			
$7^\circ = 3^\circ 47' 20''$		$7^\nabla = 4^\circ 0' 38''$		$7^\Delta = 4^\circ$			
$8^\circ = 4^\circ 20' 2''$		$8^\nabla = 4^\circ 33' 10''$		$8^\Delta = 4^\circ 34'$			
$9^\circ = 4^\circ 51' 40''$		$9^\nabla = 5^\circ 9' 23''$		$9^\Delta = 5^\circ 12'$			
$10^\circ = 5^\circ 23' 40''$		$10^\nabla = 5^\circ 43' 46''$		$10^\Delta = 5^\circ 43'$			
$11^\circ = 5^\circ 58' 20''$		$11^\nabla = 6^\circ 18' 8''$		$11^\Delta = 6^\circ 17'$		$1^m = 1^\circ 50'$	
$12^\circ = 6^\circ 32'$		$12^\nabla = 6^\circ 52' 31''$		$12^\Delta = 6^\circ 51'$		$2^m = 3^\circ 40' 43''$	
$13^\circ = 7^\circ 4' 50''$		$13^\nabla = 7^\circ 26' 53''$		$13^\Delta = 7^\circ 24'$		$3^m = 5^\circ 30' 41''$	
$14^\circ = 7^\circ 38'$		$14^\nabla = 8^\circ 1' 16''$		$14^\Delta = 7^\circ 58'$		$4^m = 7^\circ 21' 23''$	
$15^\circ = 8^\circ 11' 32''$		$15^\nabla = 8^\circ 35' 39''$		$15^\Delta = 8^\circ 32'$		$5^m = 9^\circ 12' 3''$	

For interocular
distance of .06.

For interocular
distance of .064.

Accommodation is that function of the eye that makes clear vision possible at varying distances.

This adjustment for all distances between the far point, *punctum remotum*, and the near point, *punctum proximum*, is accomplished by the action of the ciliary muscle in changing the form of the lens.

The theory of this process, which has been generally accepted, is that of Helmholtz. The ciliary muscle may be considered as made up of two parts—an outer, formed of longitudinal fibers which arise at the junction of the cornea and sclera, and pass backward to a diffuse attachment in the outer layers of the choroid, called the *tensor choroidea* or *muscle of Brücke*; and an inner portion, formed of fibers which have an approximately circular course, called *compressor lentis* or *Müller's muscle*. When the ciliary muscle contracts, the choroid and ciliary processes are drawn forward, and by the contraction

¹ This table is taken from Dennett's article on "Prisms" in a *System of Diseases of the Eye*, edited by Norris and Oliver, vol. ii. p. 148.

of circular fibers the circumference of the ciliary processes is narrowed, the zonula or suspensory ligament of the lens relaxed, and the lens, being released from the tension which this has exerted on its capsule, tends to assume a more convex shape. This hypothesis has not been seriously disputed until Tscherning, following in the footsteps of Thomas Young, developed a theory which, as it becomes more generally understood, may in part prove a dangerous rival to that of Helmholtz.

Briefly, Tscherning asserts that the accommodation does not depend on a relaxation of the zonula of Zinn, but on its tension through the agency of the ciliary muscle, whereby the peripheral portion of the lens is flattened and the curve of the anterior surface from an approximately spherical approaches a hyperboloid form. The theories of Helmholtz and Tscherning are illustrated by Fig. 90.

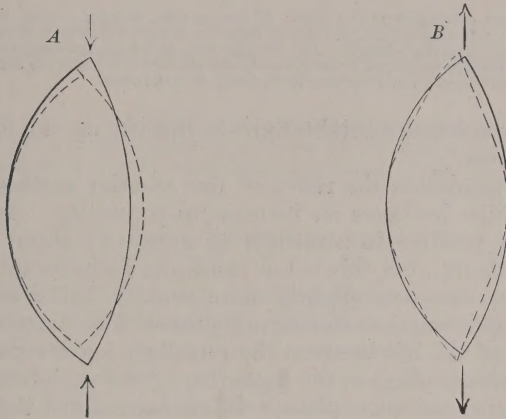


FIG. 90.—A, accommodation according to Helmholtz. The dotted line represents the thicker form assumed by the lens when the traction of the zonula is diminished by the contraction of the ciliary muscle. B, accommodation according to Tscherning. The unbroken lines show the lens at rest. The dotted lines show the change occurring during accommodation, supposed to be due to the traction of the zonula being increased by the contraction of the ciliary muscle. It will be seen that the increased dioptric power of the lens may be obtained either by relaxation of the zonula or by contraction. Tscherning believes that the changes which he has observed in the lens during accommodation prove that the latter theory is correct, while Hess (*Graefe's Arch.*, xlii. 1, S. 288; *Ibid.* xliii. 3, S. 477) opposes it strongly.

As regards the change in the lens itself, Tscherning's view seems abundantly proven by numerous experiments.¹ The action of the ciliary muscle is still undetermined. The older description, as given above, is supported by the diagrams according to Iwanoff,² but these results have not been corroborated in recent times, although they appear in some of the best text-books. Tscherning believes that the inner portion of the muscle retracts, having its more fixed attachment posteriorly in the choroid, which is steadied by the tension of the vitreous, this being increased during accommodation by the backward traction of the lens. This retraction of the oblique fibers of Müller's muscle, which is probably not as purely a circular muscle as has heretofore been described, makes traction on the zonula and produces the changes in the lens. The iris as a diaphragm cuts off the peripheral parts of the lens, so that whichever view is taken of the mechanism of accommodation the optical conditions remain practically the same.

By accommodation is meant the muscular effort, the change in the shape of the lens, and the effect produced on vision. The muscular effort is self-evident. The change in the pupillary portion of the lens is seen from the changes which the reflexes called the *images of Purkinje* undergo during accommodation. These images are catoptric—that is, formed by reflection from the cornea, the anterior and the posterior surfaces of the lens. In the

¹ Crzelltizer: "Die Tscherningsche Accommodationstheorie," *Archiv f. Ophth.*, Bd. xlii., iv. Abtheilung.

² Graefe and Saemisch: *Handbuch der Augenheilkunde*, Bd. i. p. 276.

pupillary space pictured in Fig. 91 are seen the reflections of two bright squares, one above another: *a* is reflected from the surface of the cornea, *b* from anterior surface of lens, *c* from posterior surface of lens. They are best

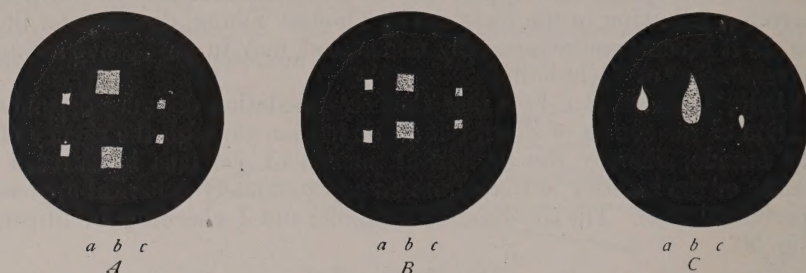


FIG. 91.—*A*, reflections during distant vision; *B*, during near vision; *a*, from the cornea; *b*, from the anterior surface of lens; *c*, from posterior surface of lens. It is seen that the reflections from the anterior surface of the lens become smaller, showing that that surface becomes more convex during accommodation. *C*, reflection of a candle flame; *a*, from cornea, sharply defined; *b*, from anterior surface of lens, large and blurred; *c*, from posterior surface of lens, small and inverted.

seen in a dark room when a bright light is thrown on the eye from the side opposite the observer.

During accommodation the reflex of the anterior surface of the lens becomes smaller, which indicates an increase in convexity. In some eyes the image changes its position in a manner to indicate a slight advancement of the surface (Helmholtz), but this is not constant (Tscherning). The posterior surface of the lens becomes slightly more convex, but does not change its position. The pupil contracts during accommodation. According to Tscherning, the portion of the iris between the pupillary border and the periphery retires a little, corresponding to the flattening of the peripheral portion of the lens which he has proven takes place. It has been stated that the tension of the anterior chamber diminishes during accommodation. Foerster (1864) observed that in patients with small keratocoeles the protrusion diminished or disappeared during accommodation, to reappear when this was relaxed.

When the accommodation is relaxed the eye is adjusted for a far point. When the greatest accommodative effort compatible with clear vision is made, the adjustment is for the near point.

Range of Accommodation.—Accommodation is measured by its effect on the vision, and the effect may be described either in terms of distance traversed between the far and near points, as measured from the eye (*range of accommodation*), or in diopters, expressing the increase of the refractive power of the lens (*amplitude or power of accommodation*). The additional strength which the lens gains may be considered as a separate lens placed in front of the crystalline.

The focal distance of such a lens being *A*, the distance of the far point from the eye *R*, and of the near point *P*, the range of accommodation would be $A = P - R$, and, as the refractive power of a lens is the inverse of its focal distance, the refractive power of the lens which we assume to represent accommodation would be

$$\frac{1}{A} = \frac{1}{P} - \frac{1}{R}$$

The application of this to emmetropia is

$$\frac{1}{A} = \frac{1}{P} - \frac{1}{\infty} = \frac{1}{P},$$

the far point being at infinity.

The power of accommodation is measured by the strength of a lens sufficient to give the rays leaving the near point the direction in the vitreous which they would have if without it they came from infinity, or in emmetropia the accommodation is measured by the dioptric value of the near point.

For example, an emmetrope whose near point was at 10 cm. would have 10 diopters of accommodation; thus:

$$\frac{1}{A} = \frac{1}{.10} - \frac{1}{\infty} = \frac{1}{.10} = 10 D.$$

A myope with a far point at 50 cm. (2 diopters of myopia) would have an accommodative ability of 8 diopters; thus:

$$\frac{1}{A} = \frac{1}{.10} - \frac{1}{.50} = 10 D - 2 D = 8 D.$$

In hyperopia only convergent rays are focussed on the retina, and the far point is a virtual focus behind the eye. It has therefore a negative value.

We may best not alter the formula, but remember that a negative sign in its last denominator makes that fraction additive, as seen in the following example, where a person whose hypermetropia is 2 *D*, and whose near point is 10. cm., is shown to have an accommodative power of 12 *D*:

$$\frac{1}{A} = \frac{1}{.10} - \left(\frac{1}{-.50} \right) = \frac{1}{.10} + \frac{1}{.50} = 10 D + 2 D = 12 D.$$

Practically, the accommodation in hyperopia equals the sum of the lens required to bring vision to infinity with that representing the dioptric value of the near distance. It will be seen from what has preceded that the measurement of the far point is equivalent to the determination of the static refraction of the eye. The near point is the nearest point at which very small type can be seen most distinctly, and is usually measured by Jaeger's test type.

Relative Accommodation.—Ordinarily, accommodation and convergence are exerted together, the eyes being directed to the point for which vision is adjusted, but a considerable latitude or independence of these functions in their relations to each other is possible. If, for instance, an emmetrope fixes at a point 33 cm. from the eye, the corresponding accommodation would be 3 *D*, but a certain amount of relaxation of accommodation and of additional power is possible with the same convergence. This relative accommodation varies for each point of fixation. The normal relations have been tabulated by Donders.¹

The practical applications are numerous. A lack of unity between accommodation and convergence is seen in the normal eye at the near point. The function of convergence being stronger than that of accommodation, the absolute near point is attained at a sacrifice of binocular vision, convergence over-acting, and thus reinforcing accommodation. In hyperopia the accommodation required is greater than the convergence, and the same tendency of the two functions to reinforce each other offers a stimulus to the latter which may result in convergent strabismus. In myopia less accommodation is required; accordingly there is less incentive to converge, and insufficiency of convergence or even divergence may occur.

Presbyopia.—The power of accommodation diminishes progressively from the earliest youth. As a result, the near point recedes from the eye, until at about the age of forty in emmetropia it reaches the distance of 22 cm., and the strength of accommodation has become about 4.5 *D*. Near

¹ *Accommodation and Refraction of the Eye*, p. 111.

vision then is rendered difficult, and from this time on convex glasses must be used to bring the near point nearer and to compensate for the diminishing power of accommodation. The cause of this change is a physiological sclerosis of the crystalline lens, which renders it less elastic in response to the force of the ciliary muscle. The table (Table II.) and accompanying curve, de-

Age.	Distance of P in meters.	Distance of R in meters.	Amplitude of A .	Presbyopia in D .
10	0.07	∞	14. D	
15	0.08	∞	12.	
20	0.10	∞	10.	
25	0.12	∞	8.5	
30	0.14	∞	7.	
35	0.18	∞	5.5	
40	0.22	∞	4.5	0.
45	0.28	∞	3.5	1.
50	0.4	∞	2.5	2.
55	0.66	-4. (H. 0.25)	1.75	3.
60	2.	-2. (H. 0.5)	1.	4.
65	-4.	-1.33 (H. 0.75)	0.5	4.75
70	-1.	-0.8 (H. 1.25)	0.25	5.5
75	-0.5	-0.5 (H. 1.75)	0.	6.25
80	-0.4	-0.4 (H. 2.5)	0.	7.

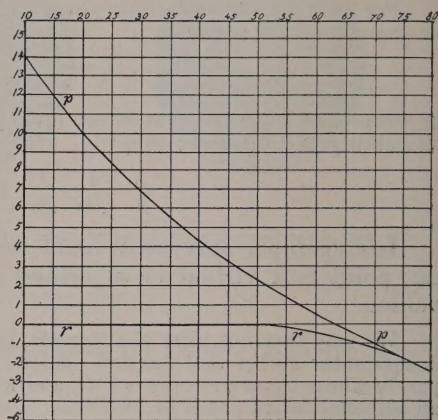


Table II., with the accompanying curve (Fig. 92), shows the relations of age to accommodation and static refraction. The table is taken from Nagel,¹ and is slightly modified. The curve is modified by Landolt from Donders.

vised by Donders, shows the decrease in the amplitude of accommodation as well as the change in the static refraction, beginning at about the age of fifty-five, by which an acquired hyperopia takes place; the curve, $p p$, represents the changes in the near point; the curve $r r$, the far point.

As has been said, presbyopia begins at the time when near vision becomes difficult. This period varies with the refraction of the eye, for the reason that the strength of the accommodation required to bring the near point to a comfortable distance depends on the position of the far point. Thus in myopia the far point is nearer the eye than in hyperopia, and the same strength of accommodation will continue the range of useful vision for near work at its proper distance later in life; that is to say, presbyopia is postponed in myopia and anticipated in hyperopia as compared with emmetropia.

It will be seen that a myope of 3 D will reach the age of sixty without discomfort, while a hyperope of the same degree would be able to overcome his hyperopia and to bring the near point to the reading distance, at the latest, up to twenty-five years.

It is important to remember that the accommodation cannot be sustained at its maximum. There must always be a reserved power, as in any other continuous work, and that is why the near point is said to be at 22 cm., allowing 0.5 D —1 D reserve above the accommodation required for the average reading distance.

The working distance is decidedly arbitrary, depending on the kind of work done or the habit of the individual as regards the distance the work is held from the eyes and on the visual acuity, for if this is diminished, the work must be brought nearer in order to obtain larger images, and the accommodation must be aided accordingly.

Visual Acuity.—Vision is measured by the size of the smallest object which can be recognized at a fixed distance in the most favorable light with the best optical adjustment. The size of the object is expressed by the visual angle formed by lines that pass through its extremities, through the nodal points of the eye, to the inverted image on the retina. The size of the image

¹ Graefe und Saemisch: *Handbuch der Augenheilk.*, Bd. vi. p. 466.

on the retina varies as the distance of the posterior nodal point from the retina, which distance is greatest in myopia and least in hypermetropia. Axial ametropia is referred to, as that is the commonest form.

When the ametropia is corrected by a lens placed at the anterior focus of the eye, the retinal image is the same size as if the eye were emmetropic.

A stronger lens is needed for the correction of myopia the farther the lens is placed from the eye, and a weaker lens suffices for hypermetropia if removed from the eye. Differently stated, this is: a concave lens loses strength and a convex lens gains strength if removed from the eye, which explains the tendency of presbyopes to slide their glasses down the nose as the presbyopia increases. It is obvious that to attain the highest visual acuity for a great distance the eye must be placed in a condition to see to the best advantage; that is to say, the ametropia must be corrected for infinity, consequently the glass that gives the highest visual acuity is the measure of the static refraction.

The distance usually chosen for the examination of vision is 6 m. So great a distance is taken because it is desirable to measure acuity uninfluenced by the effect of accommodation, and rays of light that enter the eye from any point on an object 6 m. away, however wide the pupil, are practically parallel and meet on the retina.

Snellen's type are so devised that each letter subtends an angle of five minutes, each part of a letter and each space being one-fifth of the whole in linear measurement. A visual angle of five minutes has been assumed as representing the average of a great many measurements of the eyes of individuals of all ages, and Snellen acknowledges that a great many young persons have a greater visual acuity.

It has been said above that visual acuity is measured by the ability to recognize an object at a given distance. This means that the parts of which it is composed can be differentiated: each part of one of Snellen's letters subtends an angle of one minute (Fig. 93).

The perception of a single object, however, would not be a reliable test of vision, as its visibility would depend on the intensity of the light by which it was seen, and would be, in some measure, independent of its size and the distance; for instance, a fixed star is visible, although its apparent size is almost infinitely small and its image smaller than one of the perceptive elements of the retina. Two stars, however, cannot be distinguished as separate unless they are about sixty seconds apart; that is, unless the distance between their images on the retina equals at least the breadth of a perceptive element. If the distance were smaller, both images would fall upon the same or upon adjacent elements. In the first case both would produce a single sensation, and in the second case there would be two sensations, but upon adjacent elements, so that it could not be told whether there were two points of light or one which fell upon both elements.

From the fact that the diameter of the cones in the macula corresponds quite closely to the smallest distances between the images of two objects that can be recognized as two,¹ the conclusion has been drawn that the cones are the perceptive elements.²

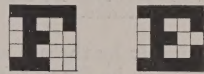


Fig. 93.—Two of Snellen's test-type.

¹ According to Kölliker, the cones in the macula lutea vary from 0.0045 mm. to 0.0054 mm. in diameter, while a visual angle of 60'' covers on the retina a space of 0.00438 mm. and one of 73'' a space of 0.00526 mm.

² Helmholtz: *Handbuch der Physiologischen Optik*, Zweite Auflage, p. 256.

Snellen's letters are arranged in lines, over each of which are Roman numerals indicating the distance, D , at which the letters of that line appear under an angle of five minutes or the distance at which they can be read by an eye of normal vision. The distance at which they can be read by the eye that is being tested is d . The formula, then, for visual acuity is $V = \frac{d}{D}$. As examinations are ordinarily made at a fixed distance of about six meters, " d " is constant, the value of the fractional expression being varied with the value of the " D " which designates the smallest legible letters, thus $V = \frac{d}{D} = \frac{6}{6}$ is normal vision. $V = \frac{6}{60}$ indicates that what the patient ought to see at sixty meters he can see at only six meters, an acuity of 0.1. It is best, however, to leave the fraction unreduced, thus recording the exact distance at which the test was made. If vision is inferior to $\frac{6}{60}$, the test types may be brought nearer, and the distance recorded at which the largest is read, as $\frac{3}{60}$. If this is not enough, the distance may be noted at which the fingers of the outstretched hand can be counted against a dark background, or, still farther, only the movements of the hand may be seen, and finally light perception only, at varying distances, or, simply, the differentiation of light from darkness (L. P.) may be all there is to record.

A better system than that of Snellen is one devised by Monoyer, in which the lines progress in tenths from 1. to 0.1. The regularity of the interval is a decided advantage, and has been utilized by Dennett with the modification that the size of every letter in each line has been so chosen as to ensure its uniform visibility.

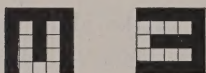


FIG. 94.—Test-type for the illiterate.

For the illiterate, characters may be used which can be described without being named, or Burchardt's series of dots may be used. The most common are the E's in different positions (Fig. 94). Guillery proposed to measure the visual acuity simply by the use of a black dot on a white ground. By comparison with the letters of Snellen he found that such a dot seen at an angle of $50''$ would correspond to the normal visual acuity; at 5 m. it would have a diameter of 1.2 mm. An acuity of one-half would be shown by the ability to see a dot of double the area at the same distance. The dots are placed in various parts of squares and are to be localized by the patient.¹

Entoptic Phenomena.—Objects in the eye in front of the sensitive layer of the retina intercept light that passes through the pupil and throw shadows which under certain conditions can be perceived. Since Listing² the examination of objects in our own eyes has been called *entoptic observation*.

If a clear sky is looked at through a pin-hole in a dark card placed near the anterior focus of the eye—the rays thus reaching the retina parallel—or if a flame at a distance of 5 m. is seen through a strong convex glass held two or three inches from the eye, a bright disk of light will be seen formed by circles of diffusion, upon which various objects are visible: (1) The traces of the lids on the cornea formed by half closing the eyes. These horizontal lines remain an instant after the pressure has ceased, and in some cases show a more lasting effect of constriction, leading to an irritable condition called "tarsal asthenopia."³ The tears and drops of mucus are seen following the movements of the lids. (2) The lens or some of its parts may become visible if a very small opening is used, the light being homocentric. Physiologically,

¹ Guillery: *Arch. für Augenheilkunde*, xxiii. S. 323.

² *Beitrag zur Physiologischen Optik*, Göttingen, 1845.

³ G. J. Bull: *Trans. Eighth Internat. Ophth. Cong.*, Edinb., 1894.

the radiating star-shaped figure of the lens and numerous small round objects like hyaline globules may be seen. These increase with age until the senile changes, the beginning of cataract, may also become apparent to the possessor in this manner (Donders). (3) In the vitreous there are always floating bodies, cells, and fibers, which as *musce volitantes* cause alarm to the nervous observer till he is assured of their insignificance. (4) A very interesting application of the entopic method is the observation of the retinal vessels (Purkinje). They may be seen in three ways:

(a) In a darkened room a candle is held at a short distance from the eye which regards the distance. The vessels come into view as dark lines on a yellowish background. They seem to move when the candle is moved.

(b) On looking through a stenopaic opening at the sky, if the opening is kept in motion, the vessels are distinctly seen, even to the smallest around the macula.

(c) If a strong light is focussed on the sclera as far as possible from the cornea, and moved slightly from side to side, the same phenomena occur. The explanation given by Heinrich Müller (1855) is that the shadow of the retinal vessels falls on the sensitive layer of the retina.

In the last experiment Müller measured the movement of a vessel projected on a surface at a known distance, and the movement of the focus on the sclera which produced this excursion, and calculated the distance behind the retinal vessel at which the sensitive layer must lie, his result coinciding very closely with the actual distance between the vessels and the layer of rods and cones.

König and Zumft¹ have recently attempted to apply this principle to the analysis of color vision, and have claimed that different colors are seen at different levels, violet being perceived by the most anterior portion of the sensitive layer, red by the most posterior. Considerable doubt has been raised, however, by Koster² as to the accuracy of these statements.

¹ Sitzungsberichte der königlich. preuss. Akademie der Wissenschaft. zu Berlin: Mai, 1894, xxiv.

² Graefe's Archiv, xli, i, S. 1.

EXAMINATION OF THE PATIENT AND EXTERNAL EXAMINATION OF THE EYE; FUNCTIONAL TESTING.

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THE value of case-records is greatly enhanced if a systematic method of examination is pursued with each patient. The following order of examination, based upon the one employed by S. Weir Mitchell in the Infirmary for Nervous Diseases, Philadelphia, is arranged for this purpose:

- Name and residence.
- Age, sex, race, married, single, or widowed.
- Family history: hereditary tendencies; general and ocular health of parents, brothers, sisters, etc.
- Personal history: children, their general and ocular health; miscarriages; menopause; former illnesses; syphilis and gonorrhea; injuries.
- Occupation: relation of work to present indisposition.
- Habits: brain-use; tobacco; alcohol; narcotics; sexual.
- Date and mode of onset and supposed cause of present trouble; outline of its course.
- Organs of digestion: teeth; tongue; stomach; bowels.
- Organs of respiration: nose; throat; lungs.
- Organs of circulation: heart; pulse; blood.
- Kidneys: examination of urine.
- Abdominal organs: liver; spleen.
- Organs of generation: menses; leucorrhœa; uterine disease.
- Nervous system: intelligence; evidences of hysteria; hallucinations; sleep; vertigo; gait; station; tendon- and muscle-jerks; paralysis; tremor; pain; subjective sensations; convulsions; headaches and their position.
- Eyes: previous attacks of inflammation; injuries; infections; ocular palsy or squint; amblyopia; previous use of glasses; ability to use eyes.
- Direct inspection and examination of eyes: inspection of the skull and orbits (symmetry or asymmetry); lids; ciliary borders; puncta lacrymalia; upper and lower cul-de-sacs; conjunctivæ; caruncles; corneæ (oblique illumination); irides (mobility and color); anterior chambers (depth and character of contents); vision; accommodation; balance of external eye-muscles; mobility of globe; tension; light sense; color sense; fields of vision; field of fixation; ophthalmoscope; ophthalmometer; retinoscope; refraction.

Necessarily the examiner will modify the thoroughness of his investigations according to the character of each case.

Direct Inspection of the Eye and its Appendages.—The *lids* should be examined for distended superficial veins, edema, tumors, for example, enlargement of the Meibomian glands, and for anomalies; their edges for inflammation, parasites, misplaced cilia, and small morbid growths; the *puncta* for permeability, deviation or retraction from the globe, pressure at the same time being made over the lachrymal sac in order to express from it, through the puncta, any contained fluid; the *caruncles* and *pliecæ* for swelling, foreign bodies, irritation by incurved cilia, and small morbid growths, for instance, polyps or angiomas; the *conjunctival cul-de-sacs* for abnormal

secretion, granulations, foreign bodies, concretions and disturbance of the vascular supply, the examination being carried well up into the upper fornix after thorough eversion of the lid.

In order to *evert the lid* the patient should rotate the eye strongly downward, while the surgeon seizes gently the central eyelashes of the upper lid between the index finger and thumb of his left hand, and draws the lid downward and away from the globe, placing at the same time the point of the thumb of his right hand above the tarsal cartilage of the lid which is to be everted, steadying his remaining fingers upon the patient's brow, and by a quick movement turns the edge of the lid over the point of his thumb, while this is simultaneously depressed. If the patient steadily looks downward during this manœuvre there is no difficulty in everting the lid without the aid of the pencil or match-stick so commonly employed as a lever.

When there are no lashes on the upper lid the manipulation is more difficult, but it can be accomplished by pushing the lower lid beneath the margin of the upper in such a manner that it acts as a wedge on which the superior lid is then everted.

The lower lid is everted readily by placing the tip of the fore finger against the edge of the lid and drawing it downward, at the same time pressing the finger backward until the lid is turned over it.

The surgeon should also inspect the skin of the face, examine for scars, and investigate the wrinkles in the forehead and between the brows. The supraorbital ridge, the general character of the orbits, and the position and shape of the globes should next be studied. *Palpation of the orbit* by passing the finger beneath the supraorbital ridge above, along the margin of the malar bone and the superior maxillary below, and to the outer and inner sides, may reveal the presence of accumulations, superficial growths, enlargement of the lachrymal gland, etc. Finally, the action of the orbicularis should be ascertained by causing the patient to close his eyes as if in sleep, and note made of the absence or presence of fibrillary contraction. When the eyes are opened the length, width, and symmetry of the palpebral fissures and the condition of the commissural angles may be studied (see page 31).

Blood-vessels of the Conjunctiva.—In health only a few conspicuous blood-vessels are to be observed; in inflammation many more become visible. The conjunctival blood-supply may be conveniently divided, as Mr. Nettleship has done, into three systems:

System I.—Posterior conjunctival vessels, whose congestion produces a bright-red, velvety color, moving, on pressure of the eyelids, with the shifting of the conjunctiva, usually associated with muco-purulent secretion and indicating conjunctivitis.

System II.—Anterior ciliary vessels composed of perforating and non-perforating arteries and veins. The perforating arteries, which supply the sclerotic, iris, and ciliary bodies are the branches seen in health entering about 5 mm. from the corneal margin, their points of entrance, in dark-complexioned people, often being distinctly tinted.

The non-perforating (episcleral) branches, invisible in the normal eye, produce, when congested, a pink zone surrounding the cornea ("ciliary congestion," "circumcorneal zone"), not moving on pressure of the lids with the shifting of the conjunctiva, unassociated with purulent discharge, and one indication of iritis.

The perforating veins and their non-perforating (episcleral) twigs, when congested, create a zone of dusky hue, often a symptom of glaucoma, or

appear in unequal deep-seated patches of lilac or violaceous color, pointing to cyclitis or scleritis.

System III.—Anterior conjunctival vessels and the plexus of capillaries surrounding the cornea, derived from anterior ciliary vessels through whose numerous small branches anastomosis between Systems I. and II. takes place. Their congestion produces a circle of bright-red injection, often partly on the cornea, a sign of inflammation of this membrane, and typified in the early vascular stages of interstitial keratitis.

In addition to these three varieties of congestion numerous departures are noticeable, making it impossible to specify the individual system involved.

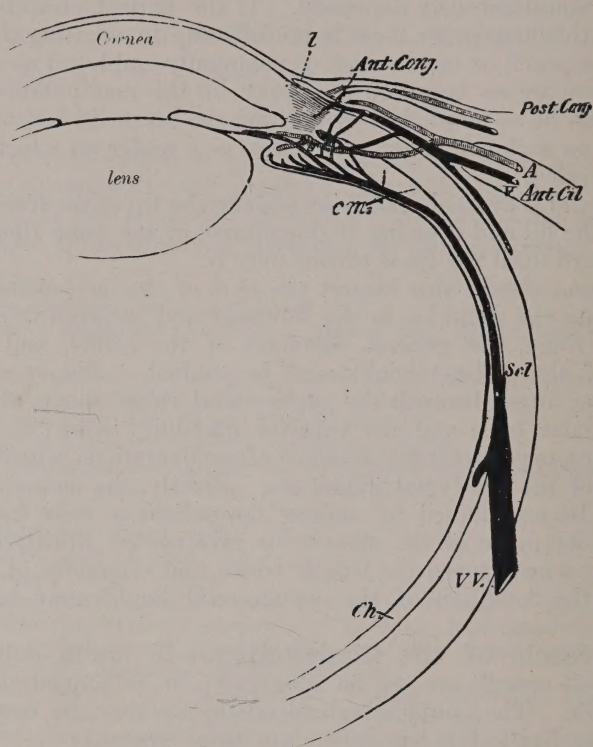


FIG. 95.—Vessels of the front of the eyeball: *cm*, ciliary muscle; *Ch.*, choroid; *Scl.*, sclerotic; *V.V.*, vena vorticiosa; *l.*, marginal loop-plexus of cornea; *Ant.* and *Post. Conj.*, anterior and posterior conjunctival vessels; *Ant. Cil.*, *A* and *V*, anterior ciliary arteries and veins (after Nettleship's alteration from Leber).

In these types is found a definite local injection, as the leash of vessels passing to a corneal ulcer; or all systems are commingled in a general inflammation.

Temperature of the Conjunctival Sac.—This may be measured with a suitable thermometer having attached to it concavo-convex mercury plates which are placed in the lower conjunctival sulcus, or, more accurately, as in physiological experiments, with thermo-electric couples. Sillex¹ found the temperature of the lower human conjunctival fold to be 35.55°C . (95.99°F .)—*i. e.* about 2°C . lower than that of the rectum,—and in inflamed eyes noted an average increase of 0.98°C . The highest conjunctival temperature is found in acute iritis, but even then does not equal the normal body-temperature.

¹ *Archives of Ophthalmology*, 1893, xxii. p. 451.

Inspection of the Cornea.—This will reveal inflammation, ulceration, opacities, the track of former blood-vessels, exudates upon its posterior surface, and foreign bodies. Slight irregularities may be detected by placing the patient before a window, while his eyes are made to follow the uplifted finger held about a foot from his face and moved in various directions; the image of the window-bars reflected from the cornea will be broken as it crosses the spot of inequality. In the same manner abnormalities in the curve of the cornea may be roughly ascertained, because if the curve is normal the reflection does not change, at least in the central portion of the cornea; if the curve is abnormal or the surface of the cornea irregular, there is corresponding distortion in the size or shape of the reflection.

A more accurate method is to employ a *keratoscope*, or *Placido's disk*, as it is called. This instrument consists of a disk shaped like a target, upon which are drawn concentric black circles, a sight-hole being in the center. The patient is placed with his back to the window, while the surgeon holds the instrument 30 cm. in front of the eye, and, looking through the central aperture, observes the reflections of the circles from the cornea. If these are broken or distorted, the indications of irregularity in the surface are present (Fig. 96). Any irregularity on the surface of the cornea is quickly detected by the method of *keratometry*, especially with the ophthalmometer of Javal and Schiötz (see page

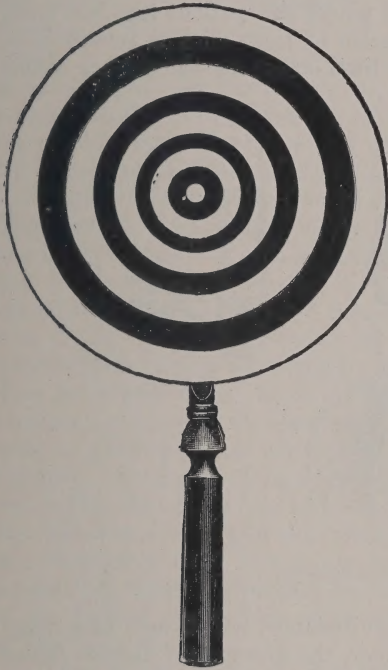


FIG. 96.—Placido's disk or keratoscope.

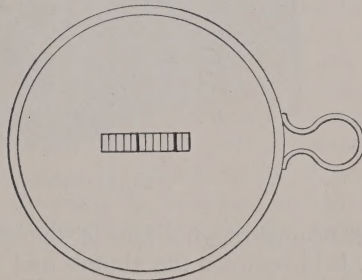


FIG. 97.—Priestley Smith's keratometer.

197), the reflections of the targets being greatly distorted as they cross the point of irregularity.

Abrasions and ulcers, even when minute, may be differentiated by dropping into the eye a concentrated alkaline solution of *fluorescein* (Grübler's fluorescein 2 per cent., carbonate of soda 3.5 per cent.), which colors greenish-yellow that portion of the cornea deprived of its epithelium, while the healthy epithelium, or even that epithelium which is simply roughened and opaque, as in keratitis, remains unaffected. A minute foreign body may thus be located if situated in the centre of an abrasion, because it appears as a black dot surrounded by a green area. So, also, may the progress of a corneal ulcer be studied, the color test differentiating sharply that portion of the ulceration which is still active from that which is covered with new-formed epithelium.

The Width of the Cornea.—This may be measured approximately by

holding before it a rule marked in millimeters and noting the number of spaces its width occupies, or, more accurately, by employing Priestley Smith's *keratometer*. This instrument consists of a scale situated between two plano-convex lenses. The surgeon places his eye at the principal focus of the combination, and, holding the scale before the patient's eye, observes that the cornea subtends on the scale exactly its width (Fig. 97). The average horizontal diameter of the normal cornea is 11.6 mm. (Priestley Smith).

The Sensibility of the Cornea.—This may be tested by gently touching the surface of this membrane with a wisp of cotton twisted to a fine point. If sensation is intact, the touch will instantly be followed by the reflex action of winking. As a control the opposite eye may be similarly examined. If the cornea is found insensitive, the forehead and face should be examined for areas of anaesthesia either with the point of a moderately blunt pin or with an *esthesiometer*. Thermic as well as tactile sensibility should be investigated.

Oblique Illumination.—The surgeon places the patient two feet from the source of illumination and focusses a beam of light with a two-inch or three-inch lens upon the cornea, at the same time observing the surface under

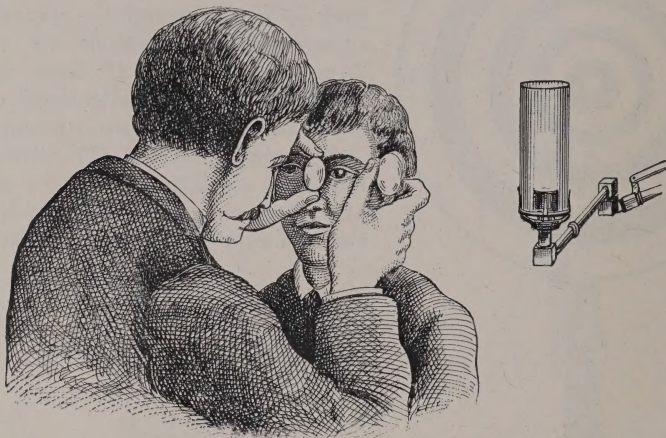


FIG. 98.—Method of oblique illumination.

examination through a lens of the same focal distance, which acts as a magnifier, held between the thumb and fore finger, the disengaged fingers being utilized to elevate the upper lid (Fig. 98). The distance of the lens must be varied slightly to bring the various tissues—the cornea, iris, or crystalline lens—within its focus, the patient being required to look up, down, and to either side while the anterior surfaces and media of the eye are illuminated. To detect a foreign body the light should be directed at an acute angle, but if the pole of the lens is to be examined the light should be thrown perpendicularly into the pupil, the surgeon placing his eye in the same direction without interfering with the light. By this method minute abrasions, foreign bodies, nebulae, and, in short, all corneal changes, may be examined. The character of the aqueous humor, the depth of the anterior chamber, the surface of the iris, synechiae, atrophic fibers, small tumors, and persisting pupillary membrane are readily studied, and, finally, opacities in the anterior capsule and axis of the lens can be investigated, and by focussing deeply even the anterior layers of the vitreous. This routine examination should never be omitted.

Recently Dr. Edward Jackson has designed a *binocular magnifying lens*

for examination of the eye by oblique illumination, which is a material aid. Two lenses are placed side by side, and so joined that the visual line of the right eye pierces the right lens near its optical center, while the visual line of the left eye pierces the left lens near its optical center. This gives each eye an undistorted field all around the point of fixation, and these fields can be combined in full binocular vision.

In place of this lens a *corneal loupe* may be employed. This is a lens, properly mounted, by which the cornea is strongly magnified. A *corneal microscope*, or a specially prepared lens of high power, permits the study of minute changes in this membrane, and is utilized for the examination of traces of former vascularization, and by its help even the circulation of blood in the vessels constituting a pannus may be studied.

The Color of the Iris.—Blue and gray are the predominating hues in the irides of the inhabitants of northern countries; brown occurs next in frequency, while the various admixtures produce yellow and green shades. Perfectly black irides are never seen, but dark irides, taking the whole population of the world, are the most frequent in occurrence. With rare exceptions the color of the iris of all new-born children is of a light grayish-blue. The stromal pigment is developed subsequently, and the color of the iris does not become fixed, so to speak, until about the third month.

Slight differences in shade between the two irides are not uncommon. More rarely, even in health, the irides differ in color (chromatic asymmetry), one being brown or greenish, the other blue or gray. Under these conditions one iris usually corresponds in color with the irides of one parent, and the remaining iris with those of the other parent. Instead of uniform pigmentation a single triangular patch or several irregular spots of dark color may appear upon one or both irides (*piebald irides*). When these spots are small they have sometimes been mistaken for foreign bodies. While chromatic asymmetry is perfectly compatible with health, it is stated to be more common in patients with neuropathic tendencies—for example, in chorea and epilepsy. In 25 of 50 cases of chorea of childhood (Sydenham's chorea) examined by the author the irides were equal in color and shade; in the remaining 25 there were slight differences in shade or tone. In only 1 of these 25 was there any true asymmetry of color. In some instances of chromatic asymmetry there is liability to disease, especially to cataract, on the part of the lighter eye. This susceptibility may be present in several members of the same family.

Discoloration from disease causes one iris to be green, while its fellow remains blue. This indicates iritis or cyclitis. It is often an early symptom of inflammation of the iris, and should be looked for in every inflamed eye.

The Pupil.—The size of the pupil in health varies with exposure to light and with accommodation and convergence. It is also influenced by age, the color of the iris, and the character of the refraction. Other things being equal, the pupil is generally smaller in old age, in blue eyes, and in eyes with hyperopic refraction, while it is larger in youth, dark eyes, and eyes with myopic refraction. There is no physiological standard on which to base a measurement, but with accommodation at rest the diameter of the pupil varies from 2.44 to 5.82 mm., the average diameter, according to Woinow, being 4.14 mm. Under similar illumination the pupils should be round and of equal size, although a large number of measurements—for instance, those made among healthy military recruits—indicate that slight differences in the width of the pupils are compatible with health.

Measurement of the Pupil.—The pupil can be measured approximately by holding before it a rule marked in millimeters and noting the number of spaces its width occupies. The chief objection to this method is, as Edward Jackson points out, that the distance subtended on the rule is less than the diameter of the pupil, in proportion as the distance from the observer's eye is less to the rule than to the pupil. For the purpose of accurate measurement a number of instruments have been devised, known as *pupillometers*. A simple and useful device is one which consists of a scale of circles held close to the observed eye, the scale being slowly rotated until that circle which matches the pupil in size is reached (Fig. 99). Priestley Smith's

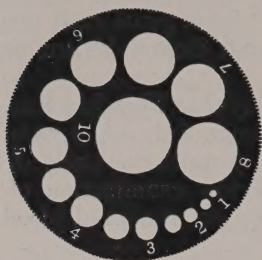


Fig. 99.—Simple pupillometer.

keratometer (Fig. 97) can also be employed.

The Pupil-reactions and Methods of Testing Them.—A uniform light should be employed and the character of the light should be stated. As Turner insists, the light employed for testing the sensitiveness of the retina or visual center should not be more intense than that to which the eye is usually accustomed. Therefore, except under certain circumstances, examinations made by reflecting light into the eye with a mirror or by passing a flame in front of the eye are not accurate. It is much to be regretted that in recorded examinations such loose statements as "pupils dilated," "pupils contracted," "pupils medium-sized," have been so much used.

Mobility of the Iris.—The reflex mobility of the pupil¹ is tested to ascertain the presence of attachments between the iris and the lens (*synechiæ*), or immobility from atrophy of the iris, or to examine the sensitiveness to light of the retina or visual center.

(a) The patient, placed before a window in diffuse daylight, with one eye carefully excluded, is directed to look into the distance with the exposed eye, which is then shaded, when, in the absence of abnormalities, a considerable dilatation of the pupil will occur. On removal of the covering hand or card, contraction to the same size as that which existed before the test was applied takes place. This is the *direct reflex action of the pupil*, and is brought about by a muscular contraction of the sphincter of the iris following the stimulation of the optic nerve.

(b) If during this examination the other pupil, which has been shaded by a card or covering hand, is observed, it will be found acting in unison with its fellow. This is the *consensual or indirect reflex action of the pupil*. The iris response to light-stimulus should also be tested with both eyes open and exposed to the same source of illumination. The eyes should then be covered and exposed alternately and the pupil-reactions noted. Under normal conditions the pupils should be equal, not only with both eyes open, but with one eye shaded.

(c) If the patient is required to look into the distance and then quickly direct his eyes at a near object—for example, the point of a pencil held at a distance of about 10 cm.—pupillary contraction occurs under the influence of accommodation and convergence; that is, the sphincter of the iris contracts in association with the ciliary muscle and the internal recti. This is the *associated action of the pupils (convergence-reaction)*. Accommodation in-

¹ It is customary to speak of the action or reaction of the pupil, although really the mobility of the iris is ascertained. For convenience: "mobility of the iris" is synonymous with "pupil-reaction."

creases pupillary contraction, but this does not take place under the influence of accommodation unassociated with convergence. It does occur with convergence without the act of accommodation.

(d) A second reflex action of the iris, the other being its contraction under the stimulus of a beam of light (direct light-reaction, paragraph a), consists of a dilatation of the pupil when some cutaneous nerve is stimulated, especially one in the skin of the neck. This is the *skin reflex* (*pain-reaction*), and may be tested by pinching the skin of the neck, or, better, by using a faradic brush.

(e) Finally, the reaction of the iris to the mydriatics and myotics may be tried, especially that produced by cocain, which in the normal eye should cause nearly full mydriasis and widening of the palpebral fissure from stimulation of the sympathetic. (For the physiology of pupil-phenomena see page 96.)

Abnormal Pupillary Reactions, or the Pupil in Disease.¹—When about to investigate pupil-reactions six possibilities, as William McEwen points out, should suggest themselves to the examiner—namely, (a) The action of drugs; (b) ocular disease or optical defects; (c) spinal or sympathetic lesions; (d) localized cerebral lesions in special centers or tracts; (e) abeyance of brain-function; (f) cerebral irritation. For the convenience of ascertaining in what portion of the path of the pupil-reflex the lesion is situated Magnus² has divided it into the following three portions:

1. *The Centripetal Part, including the Optic Nerve, Chiasms, Tracts, and Connecting Fibers to the Cortex.*—If there is interruption of the conducting power of one optic nerve—for example, the right—illumination of the pupillary area on that side fails to elicit either the direct or the indirect reflex action of the pupil. On the other hand, illumination of the left eye causes its own pupil to contract (direct reflex), as well as the pupil of the right or affected eye (indirect reflex).

Lesions affecting the chiasm and the tract are accompanied by hemianopsia (see page 481) and the special pupillary phenomena which belong to this condition, while lesions in the optical pathway between the corpora quadrigemina and the cortex, although accompanied by probable changes in the visual field, are unassociated with pupillary disturbances.

2. *The Part of the Reflex Ring which carries the Light Impulse from the Corpora Quadrigemina to the Oculo-motor Nuclei (Meyner's Fibers).*—If both sides are affected, neither pupil reacts to the impulse of light falling on either eye, but there is normal reaction to accommodation and convergence. (See Argyll-Robertson symptom, below.)

3. *The Centrifugal Portion of the Reflex Ring (the Nucleus of the Sphincter of the Iris, the Third Nerve, and the Termination of the Third Nerve in the Iris).*—If the right nucleus is affected, the direct light-reflex action of the right pupil is abolished, and also its indirect reflex. A beam of light directed into the left eye is followed by pupil-reaction in that eye (direct reflex). Pupil-reaction in that eye also follows light stimulus of the opposite or right eye (indirect reflex), but is somewhat lessened in degree. The pupils react normally to accommodation and convergence, and are unequal, the right being the wider.

If the trunk of the right oculo-motor is affected, there is pupillary immobility under the influence of light directed into the right eye, and also when it is directed into the left eye, as well as loss of accommodation upon the right side. Light falling into the left eye produces on this side a normal reaction which is also manifested if the light is directed into the opposite eye. The pupils are unequal, the right being the larger. Similar conditions arise if the peripheral fibers of the oculo-motor at their termination in the iris are affected upon one side.

We have now to consider a little more in detail:

1. **Dilatation of the Pupil (Mydriasis).**—This occurs in ocular disease—for instance, glaucoma—in cases of non-conductivity of light (optic-nerve atrophy), in orbital disease, and under the influence of mydriatic drugs. It is further seen in fright, emotion, anemia, in depressed nervous tone, neurasthenia, aortic insufficiency, and irri-

¹ The following paragraphs are abstracted from the author's chapter on "Diseases of the Optic, Oculo-motor, Pathetic, and Abducens Nerves," in *A Text-Book of Nervous Diseases by American Authors*, edited by F. X. Dercum, 1895, pp. 794-803.

² *Klin. Monatsbl. f. Augenheilk.*, xxvi. p. 255.

tation of the cervical sympathetic. It is noticed in vomiting, forced respiration, and anemia of the brain—for example, syncope—and is said to be present in persons of low mental development.

In disease of the nervous system dilatation of the pupil, when of cerebral origin, indicates extensive lesion; when of spinal origin, irritation of the part (McEwen). Systematic writers have divided dilatation of the pupil into *irritation-mydriasis*, caused by irritation of the pupil-dilating center or fibers, and *paralytic mydriasis*, caused by paralysis of the pupil-contracting center or fibers, or by failure of the stimulus to be conducted from the retina to the center.

The former is apt to be seen in hyperemia and irritation of the cervical portion of the spinal cord, in spinal meningitis, in cases of tumor of the spinal cord, and also, under certain circumstances, in tumor of the cerebral contents, in psychical excitement—for example, acute mania—and in tabes dorsalis and progressive paralysis of the insane.

The latter, which is also known as *iridoplegia*, is found in disease at the base of the brain affecting the center of the third nerve, in pressure of the cerebrum when in great amount, as from hemorrhage, tumors, advanced thrombosis of the sinuses, or large abscesses; also in the late stages of meningo-encephalitis. It is said to be present in acute dementia when there is edema of the cortex, and is found in cerebral softening. Hemorrhage into the centrum ovale and cerebral peduncles also produces mydriasis (McEwen).

2. Contraction of the Pupil (Myosis).—This appears in congestion of the iris, paralysis of the sympathetic and also of the fifth nerve, in certain fevers, in plethora, venous obstruction, mitral disease, and under the influence of myotics.

If the myosis is of cerebral origin, it indicates an irritative stage of the affection; if of spinal origin, a depression, paralysis, or even destruction of the part (McEwen). Systematic writers divide contraction of the pupil into *irritation-myosis*, caused by irritation of the pupil-contracting center or fibers, and *paralytic myosis*, caused by a paralysis of the pupil-dilating center or fibers, or by a combination of both.

Irritation-myosis, as just noted, is found in the inflammatory affections of the brain and its meninges—*e. g.* meningitis, abscess (at first the myosis is on same side as lesion), and beginning sinus-disease. According to the rule previously given, myosis may change to dilatation if the products of disease become excessive; hence the serious prognostic import of mydriasis under these circumstances. Myosis is seen in the early stages of cerebral tumor, in small hemorrhages into the cerebellum, and at the onset of cerebral apoplexy. Berthold, quoted by Swanzy, uses myosis as a diagnostic symptom between apoplexy and embolism. McEwen points out that the convulsions arising from meningo-encephalitis are accompanied by myosis, while those due to epilepsy are usually associated with mydriasis. Apoplexy of, or pressure upon, the pons is associated with myosis.

Paralytic myosis (spinal myosis) occurs in lesions of the cord above the dorsal vertebra. It is especially noteworthy in tabes dorsalis. At first the pupil reacts to light and convergence, but later exhibits the *Argyll-Robertson phenomenon* (or *reflex iridoplegia*); that is, it responds only slightly or not at all to the light-impulse, but the associated action of the iris—or, in other words, the contraction of the pupil in accommodation and convergence—is preserved. The lesion under these circumstances is probably in the fibers which pass from the proximal end of the optic nerve to the oculomotor nuclei. Turner contends that a single lesion in the fore part of the oculomotor nuclei in the Sylvian gray matter is the cause of both myosis and reflex iridoplegia.

Paralytic myosis is also met with in paralysis of the insane, pseudo-dementia paralytica of syphilitic origin, bulbar palsy when complicated with progressive muscular atrophy or sclerosis of the brain and spinal cord, and, according to Mills, in some forms of multiple neuritis. The iris reacts peculiarly to mydriatics, which dilate this type of pupil only partially, and their effect is for a long time manifest. Cocain, however, readily expands the small pupil of reflex iridoplegia (Heddaeus). Myotics contract it *ad maximum*.

Unilateral reflex iridoplegia, or that condition when one pupil is unaffected by varying degrees of illumination of both eyes, but reacts to accommodation, the unaffected pupil responding to separate light-stimulus of either eye, may exist with or without mydriasis, and usually is wider than its fellow. It is seen in tabes dorsalis and syphilitic cases. It is probably due to lesion in the sphincter nucleus. It should be distinguished from unilateral reflex blindness (see ¶ 1, p. 149).

The reverse of the Argyll-Robertson symptom has been observed, and indicates disease in a special part of the oculomotor nucleus.

Unequal pupils (anisocoria) are rarely seen in health, although it is stated by one observer (Iwanow) that among 134 healthy military recruits the right pupil was

larger in 49 and the left in 53, equal width being found in only 12. If there is recent wide dilatation of one pupil and no disease of the eye, the instillation of a mydriatic may be suspected. Unequal pupils occur in eyes with widely dissimilar refraction if one eye is blind, in aneurysm, dental disease, traumatism, and in diseases of the nervous system. If the disease is cerebral, unequal pupils denote unilateral or focal disease. They are not uncommon in tabes, disseminated sclerosis, and paralytic dementia.

Varying inequality of the pupils, or a mydriasis now occurring on the one side and now on the other, is, according to Von Graefe, a serious premonitory symptom of insanity.

Special Pupillary Phenomena.—The hemiopic pupillary inaction is referred to on page 480. The *cerebral cortex reflex of the pupil* (Haab's reflex) consists of a marked bilateral pupillary contraction which takes place if the patient sits in a darkened room and directs without change of accommodation or convergence his attention to a bright object already present within the compass of the field of vision.

Galassi and later Harold Gifford have described an *orbicularis pupillary reaction*—that is, a contraction of the pupil when a forcible effort is made to close the lids. This occurs as the result of an overflow stimulus, attempted closure of the lids exciting in the nucleus of the orbicularis fibers of the facial an activity which is transferred to the pupil-contracting center. The test is of use in determining whether the pupil sphincter is paralyzed. The phenomenon has also been described by Westphal and Piltz.

Paradoxical Pupil-reactions.—Dilatation of the pupil under the influence of light-stimulus, and contraction when it has been shaded, have been described in cases of meningitis. A good deal of doubt has been cast upon this type of pupil-reaction.¹

Hippus, which is a normal phenomenon for a few seconds after light-stimulus to the retina and optic nerve, consists of a rhythmical contraction and dilatation of the pupil occurring without alteration of illumination or fixation. It is seen in cerebro-spinal sclerosis, disseminated sclerosis, neurasthenia, hysteria, psychical disturbances, epilepsy, and acute meningitis in its early stages.²

Testing Acuteness of Vision.—For the purpose of determining acuity of sight test-types are employed, in which the letters are of various sizes and are constructed according to the methods described on page 138.

Inasmuch as many good eyes possess a vision of five-fourths of the standard angle, Dr. James Wallace of Philadelphia and Dr. Culver of Albany have arranged a series of test-types in which, instead of an angle of five minutes, one of four minutes has been substituted as the basis of each letter.

Dr. Randall points out that the order of the letters should be adjusted so as to bring the confusion-letters in the same alternation. It is preferable to have large letters at the top of the card, no particular advantage accruing from the inverted arrangement. The color of the card is of importance, a cream color verging on the India tint giving the best definition through lessening of irradiation (Randall). White letters on a black background are also employed.

When it is desired to test the acuity of sight, the patient is placed 6 meters from the type-card, in a well-lighted room, and each eye is tried separately. If the letters of No. 6 (20 feet, approximately) are read, vision is normal or 1, but if at the same distance no smaller letters than those numbered 18 (60 feet) can be discerned, vision is $\frac{1}{3}$. It is usual to express these results accord-

ing to the formula, $V = \frac{d}{D}$, in which V stands for visual acuteness, d for the distance of the patient from the card, and D for the distance at which the type should be read, so that in these instances the vision would be recorded $\frac{6}{60}$ and $\frac{6}{18}$, or in feet $\frac{20}{XX}$, $\frac{20}{LX}$ (see also page 140).

Any other distance may be chosen, provided it does not place the patient

¹ For a full account of this condition see *Gaz. hebdom.*, No. 62, 1896.

² The author desires to acknowledge much indebtedness to Swanzy's chapter on "The Motions of the Pupil" in the preparation of the section devoted to the pupil.

closer to the test-card than 3 meters, at which close range the function of accommodation would introduce an element of inaccuracy. Thus, the scale made use of by De Wecker and elaborated by Oliver assumes $\frac{5}{6}$ ($\frac{15}{XV}$, approximately), instead of $\frac{6}{6}$ as $\frac{1}{1}$. In like manner, a 4-meter distance may be utilized, as has been done by Edward Jackson. Rays coming from letters at 6, 5, or 4 m. have so little divergence when they reach the eye that they are usually considered parallel; hence if the patient sees distinctly at this distance, his vision is perfect at the longest range. In point of fact, however, as Frederick K. Smith has insisted, there is an appreciable divergence of rays from the distances mentioned, equivalent respectively to $\frac{1}{6}$, $\frac{1}{5}$, and $\frac{1}{4}$ diopter lens. In the final adjustment of glasses this divergence should be recognized.

For the purpose of a control test, and also for determining the visual acuity of illiterate persons, cards are employed on which a number of black dots and disks of various sizes are placed, which should be counted at different distances. Among the best known of these are Burchardt's "international tests." For the same reason Edward Jackson has designed a visual test which is an incomplete square, the incomplete side being turned successively in different directions (see also page 140). A useful test for children may be constructed by printing on a card small pictures of well-known objects which in size shall approximately conform to the standard angle. Such a series has been published by Dr. Wolffberg of Breslau.

If the patient fails to decipher the largest letter at the distance employed, he should be moved closer to the card. Thus, he may be unable to read the type numbered 60 at 6 m., but may discern this at 4 m., $V = \frac{4}{6.0}$ or $\frac{1}{1.5}$ of normal. Still further depreciation of visual acuity is recorded by requiring the subject to count the outstretched fingers at various distances ($\frac{1}{2}$, 1, or 2 m.), $V =$ counting fingers at the distance measured. When the ability to distinguish form (qualitative light-perception) no longer exists, the perception of light should be tried by alternately screening and shading the eye, or by illuminating the eye with light reflected from a mirror or focussed through a magnifier.

Light-sense.—Having determined the acuity of vision by means of the test-letters, the examiner has ascertained the form-sense, and may proceed to

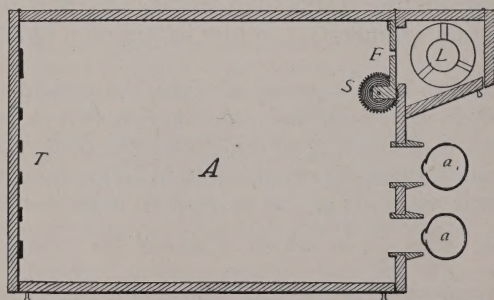


FIG. 100.—Photometer of Förster (Fuchs).

investigate a second subdivision of the sense of sight, the light-sense, which is the power possessed by the retina, or center of vision, of appreciating variations in the intensity of the source of illumination. An instrument called a *photometer* is employed for this purpose, and consists essentially of an apparatus by which the intensity of two sources of light may be compared—as, for

example, in the apparatus of Izard and Chibret. The patient, looking into the instrument, sees two equally bright disks. One disk is now made darker, and the power of the eye to perceive the difference in the illumination of the two disks is ascertained; or one disk is made entirely dark and then gradually illuminated, and the smallest degree of light noted by which the patient can perceive the disk coming from the darkness. The former is called *light-difference* (L. D.), and the latter *light-minimum* (L. M.).

Other instruments have been invented by Förster, Landolt, and R. Wallace Henry.¹ By means of Förster's photometer (Fig. 100) the lowest limit of illumination with which an object is still visible (the *minimum stimulus*) is ascertained. The following description is taken from Fuchs:

"A box, *A*, blackened on the inside, bears on its anterior wall two apertures for the two eyes, *a, a*, which look through these apertures at a plate, *T*, which is fastened upon the posterior wall, and upon which large black stripes upon a white ground are placed as test objects. The illumination is produced by a candle of one-candle power, *L*, the light from which falls through a window, *F*, into the interior of the box. In order to make the illumination perfectly uniform, the window is covered with paper which is made translucent by impregnating it with fat. By a screw, *S*, the size of the window can be altered from complete closure up to an aperture of 5 square cm. The patient is made to look into the apparatus with the window closed, and the plate therefore unilluminated. Then the window is slowly opened until the stripes upon the plate can be recognized. The size of the opening requisite for this purpose gives a measure of the light-sense of the person examined. In conducting this examination the precaution must be adopted of making the patient stay beforehand in the darkness."

Some information in regard to the light-sense may be obtained by testing the acuity of vision on two cards under a different degree of illumination, and by comparing the results with a similar examination of a subject believed to have normal power of appreciating different degrees of illumination. The patient with normal light-sense will be able to recognize the printed letters when the patient with defective light-sense is unable to read them. It is very important in many cases, especially of slight retinal change, to ascertain the acuity of sight under full and under diminished illumination.

Color-sense.—A third subdivision of the sense of sight is the color-sense, or the power which the retina has of perceiving color, or that sensation which results from the impression of light waves having a certain refrangibility. This examination is of especial interest in the detection of *color-blindness* (see page 603).

Measurement of the Vision for Colors.—Various methods are employed for ascertaining the qualitative and quantitative vision for colors. Direct vision for colors may be studied by placing the patient at a given distance—for example, 5 m.—from a chart or disk of graduated colors. In the scale of De Wecker and Masselon the colored surface, 2 cm. square, should be recognized at 5 m.; that is, the chromatic vision V_C or $C = 1$; if a colored test must be four times this size in order to be recognized, $C = \frac{1}{4}$, etc. (True and Valude). Charles A. Oliver has designed a convenient apparatus for measuring the color-sense in this manner at a given distance, and has found that red requires $2\frac{2}{3}$ mm. of surface exposure to be properly recognized by the normal eye at 5 m. distance; yellow, a slightly increased area; blue, $8\frac{3}{4}$ mm.; green, $10\frac{3}{4}$ mm.; and violet, $22\frac{3}{4}$ mm.

Selection Tests.—Usually one or other of the methods which consist essentially in testing the power to match colors conveniently used in the form of colored yarns is employed. Practically, all of these tests are modifications of Holmgren's wools, a specially commendable method being that devised by

¹ *Ophthalmic Review*, xv., Feb., 1896.

Dr. William Thomson. (For the full consideration of these tests consult page 603.)

Special Tests.—In order to obviate the change which occurs in the color of yarns, etc. the color-sense may be investigated by the *spectroscope*, which, however, is not convenient for office-work. The changeable colors, which are colored mixtures like those of wools, may be produced by passing polarized light through a quartz plate and again through a Nicol-prism.

The following account, condensed from Carl Weiland's¹ description of the Javal-ophthalmometer as a *chromatometer*, gives the essential points of instruments constructed for this purpose, and of his own happy modification of the ophthalmometer:

In the *color-measurer* of Rose the light is passed through a Nicol-prism first, and then by a diaphragm through a double refracting prism, from where it enters first a quartz plate cut at right angles to its optic axis, and finally a second Nicol-prism. Two circles of complementary colors are thus produced, which change continually when the upper quartz and Nicol-prism are rotated, but always remain complementary to each other. König's *ophthalmo-leukoscope* is like Rose's instrument, except that the first Nicol-prism is wanting and that quartz plates of different thickness—5, 10, or 15 mm.—are used, according to the degree of color-saturation required.

In Chibret's *chromato-photo-optometer* the quartz plate is cut parallel to its optic axis, and the change in colors is obtained by inclining the plate at different angles to the line of vision. As these instruments are expensive, Weiland has devised a *chromatometer* which he describes as follows:

The color attachment to Javal's keratometer consists "of a straight metal tube, about $1\frac{1}{2}$ inches in diameter, reaching from the place where the patient's cornea usually is to about the beginning of the barrel of the telescope, and so fastened to the head-rest that its axis coincides with the axis of the instrument. At the front part of this color-tube there is a plane glass plate behind which a Nicol-prism is fastened in a cork. From this prism the polarized light passes by a round diaphragm through a quartz plate, cut at right angles to its axis and about 5 mm. thick.

"The patient, looking with the Javal through this tube, will see two large color-fields partially overlapping each other. These color-fields are of complementary hues, while the place of overlapping shows white; provided, of course, that white light as reflected from a white surface, like a piece of white paper, is employed in this experiment. If now the arc of Javal be rotated, while the color-tube remains in the same position, the colors will change continually, but always remain complementary, returning, however, to their original hues after the arc has been rotated through 90° .

"For the purpose of examination, place the patient's eye at the ocular of the instrument, after you have first looked in yourself and given to the new color-tube such a position that blue and yellow appear, because thus most color-blind persons will recognize two different colors. Now ask the patient whether the two colors are exactly alike or at least shades of the same color. If he answers *No*, turn the barrel of the Javal slowly through 90° , telling the patient to stop you as soon as the two colors are the same. If he has good color-sense he will always see two different colors, but if he is color-blind, he will find that in a certain position of the arc the two colors will appear alike, or at least as much alike as if they were shades of the same color. These colors will usually be green and rose for a green-blind person, while the red-blind person generally selects a more bluish-green and a rose with much more red in it. This suffices to prove that the case is color-blind."

Pseudo-isochromatic Tests.—According to Mauthner, certain colors which the normal eye differentiates appear to the color-blind person "falsely of the same color"—*i. e.* pseudo-isochromatic. At one time the color-blind subject will describe as alike a row of colors which are not so; at another time, when the test relates to the recognition of letters or signs on a colored ground, he will not see them, especially when the color of the ground and the letters (figures, signs, etc.) are pseudo-isochromatic and equally clear.

Daae has placed upon a card on which are fastened ten horizontal rows of variously colored wools one row which contains only red wools, one which con-

¹ *Archives of Ophthalmology*, xxiv., 1895, p. 349.

tains only green, and one which contains only purple. In the other seven rows the various colors are placed next to each other. The color-blind person designates rows as of the same color when this is not the case and the reverse. A test of this character, according to Mauthner, is a *positive pseudo-isochromatic* test, because it depends upon the positive expressions of the patient in regard to color similarity.

Of the *negative pseudo-isochromatic* tests—negative because, according to Mauthner, they depend upon the fact that the color-blind person does not read figures or letters which are drawn upon a pseudo-isochromatic ground—the plates of Stilling may be mentioned (see page 604). Pseudo-isochromatic powders have also been prepared by Mauthner for the same purpose.

Simultaneous contrast tests based upon experiments with colored shadows are not satisfactory in practical work. Meyer's discovery that if a gray ring or border is placed upon a colored—for example, red—piece of paper, and then covered with tissue-paper, it will appear to the normal eye in the complementary color—that is, green—has been utilized for practical work, particularly in the letters devised by Pflüger. These consist of black or gray letters upon a colored ground. The letters are then covered by tissue-paper and appear in the complementary color.

Lantern-tests are sometimes employed, and are of great value in the examination of railroad employes (see page 604).

Accommodation is measured in practical work by finding the nearest point at which fine print can be clearly deciphered. The types most frequently adopted are those known as Snellen's 0.5 or Jaeger's 1. Frequently, however, the types in common use are very badly printed and constructed. The letters should be so arranged that they subtend the standard angle of five minutes at a given distance; for example, 25 cm., 50 cm., etc. Ordinarily, these letters are arranged upon suitable cards. Excellent series have been published by Schweigger, by James Wallace, and by Charles A. Oliver.

In order to study the phenomena of accommodation the student should record—(1) The nearest point of perfectly distinct vision attainable with the smallest readable type, or the *punctum proximum* (abbreviated *p. p.*, or simply *p.*). (2) The far point of distinct vision, or the *punctum remotum* (abbreviated *p. r.*, or simply *r.*). (3) The *range, amplitude* of accommodation, or the expression of the amount of accommodative effort of which the eye is capable. This is expressed in the number of that convex lens placed close to the cornea whose focal length equals the distance from the near point to the cornea, and which gives rays a direction as if they had come from the far point; thus, if the near point be at 10 cm., the lens which expresses the amplitude of accommodation is $+ 10 \text{ D. } \frac{100}{10} = 10$. A convenient measure is a stick marked

on one side in inches and fractions of an inch, on the other side in millimeters and centimeters; on the edge the amplitude of accommodation is expressed in diopters. (4) The *region* or the *space* in which the range of accommodation is available. (5) *Relative accommodation*, or that independent portion of this function which can be exercised without alteration in a given amount of convergence, and is divided into a *negative* portion, or that portion which is already in use, and a *positive* portion, or that portion which is not in use. If the patient is unable to read the fine test print at any distance, a convex lens should be placed before the eye and the near point and far point recorded with its aid (see also page 134).

Mobility of the Eyes.—This is tested by causing the patient to follow with his eyes, the head remaining stationary, the movements of the uplifted

finger, which is directed to the right, to the left, upward, and downward. Both eyes must be observed, and note made of any lagging in their movements or of the failure of either eye to turn into the nasal or temporal canthus. At the same time, the relation of the movements of the upper lid to those of the eyeball is recorded. The attention of the patient must be centered upon the moving finger, and allowance should be made for the imperfect mobility of highly myopic eyes. Any asymmetry of the skull, or difference in the level of the two orbital margins, may be observed, because such conditions are not infrequently associated with ametropic eyes, especially when the two eyes possess great inequality in refractive conditions.

Investigation of the Balance of the External Eye-muscles.—

Under normal conditions perfect equilibrium of the external eye-muscles is present, but preponderance, for example, of the power of the external recti, or *vice versa*, produces a tendency to divergence or convergence, which, however, is overcome, with the preservation of binocular single vision, in spite of the disturbed equipoise. This condition was named by Von Graefe *dynamic strabismus*. It is frequently designated *insufficiency of the ocular muscles*. Disturbance of the normal balance (*imbalance*, as it is now called) creates a tendency for the visual lines to depart from parallelism, or the various *phorias* of G. T. Stevens's classification. In order to ascertain the condition of the ocular muscles, in so far as their balance is concerned, we may employ the following tests:

(1) Approach the finger to within a few inches of the eyes, which are steadily fixed upon its tip, and note if a convergence to a distance of 8 cm. ($3\frac{1}{2}$ in.) is attainable.—If one eye deviates outward before this point is reached, weakness of the interni is present, the eye possessing the weaker internus usually being the one which exhibits the deviation. This test is a rough one, and valuable chiefly for ascertaining which of the interni is the weaker.

(2) Require the patient to fix upon a fine object, as a pin-point, held below the horizontal, 20 or 25 cm. from the eye, and, in order to remove the control of binocular vision, cover one eye with a card or the hand, and observe whether the eye under cover deviates inward or outward, and returns to fixation when the cover is removed. If the patient fixes the object accurately, and the manipulations of covering and uncovering first one eye, and then the other, are rapidly performed, trustworthy results will be obtained. In general terms, each millimeter of movement of the deviating eye corresponds to 2° of insufficiency as measured by prisms. In the case of the interni, if the covered eye moves in to fix, with several distinct impulses, each impulse should be multiplied into the foregoing result (Randall).

(3) Produce vertical diplopia with a prism, and test the functions of the lateral muscles at a distance of 6 m.

A small flame is placed against a dark background at 6 m. from the patient and on a level with his eyes. In an accurately adjusted trial frame a prism of 7° is inserted, base down, before one eye—for example, the right. Vertical diplopia is induced, and the upper image belongs to the right eye. If the flames stand one directly over the other, there is no inclination to divergence or convergence. If the upper image stands to the left, there is weakness of the interni; if to the right, of the externi. That prism placed with its base in or out before the left eye, according to circumstances, which brings the two images into a vertical line, measures the degree of the deviation.

Thus the presence or absence of *lateral insufficiency* is determined.

(4) Produce lateral diplopia, and test the functions of the vertical muscles at a distance of 6 m.

The patient is seated as before, and a prism of sufficient strength to induce homonymous diplopia is placed before one eye—for example, the right—*i. e.* with its base toward the nose. If the images are on the same level, no deviating tendency is present. If the right image rises higher than the other, the visual line of the right eye tends to be lower than that of its fellow, and there is *insufficiency of the vertical muscles*. That prism, placed with its base down before the left eye, which restores the images to the horizontal level measures the degree of deviation.

(5) Produce vertical diplopia, and test the functions of the lateral muscles at the ordinary working distance, or 30 cm. For this purpose it is customary to employ the equilibrium test of Von Graefe, in which a card, having upon it a large dot through which a fine line is drawn, is held 25 or 30 cm. from the eyes, diplopia being induced by means of a prism of 10° or 15° , base up or down, before one eye. A more accurate test-object is a small dot and fine line, or a single word printed in fine type, requiring accurate fixation and a sustained effort of accommodation. If, the prism being placed base down before the right eye, the images stand exactly one above the other, equilibrium is evident; if the upper image (image of the right eye) stands to the left of the lower image, there is *crossed lateral deviation*; and that prism, placed before the left eye with its base toward the nose, which restores the image to a vertical line measures the tendency to divergence, *exophoria*, or insufficiency of the internal recti. If the upper image stands to the right of the lower, there is *homonymous lateral deviation*; and the prism placed before the left eye, with its base toward the temple, which restores the images to a vertical line, measures the tendency to convergence, *esophoria*, or insufficiency of the external recti.

(6) Ascertain the power of adduction (prism-convergence), abduction (prism-divergence), and sursumduction (sursumvergence) by finding the strongest prism which the lateral and vertical muscles can overcome.¹

Beginning with *adduction*, find the strongest prism placed before one eye, with its base toward the temple, through which the flame still remains single. The test should begin with a weak prism, the strength of which is gradually increased until the limit is ascertained. This varies from 30° to 50° . In this test, if diplopia occurs when, for example, the strength of the prism reaches 20° , single vision may not return until the prism has been reduced, for instance, to 10° . The space between the greatest and least power of adduction has been described as the "region of diplopia" (Reeves, Lippincott, Gould).

In like manner *abduction* is tested, the prism now being turned with its base toward the nose; 6° to 8° of prism should be overcome. The ratio between adduction and abduction should be 6 to 1 (Stevens)—*i. e.* if adduction is 48° , abduction should be 8° , but, according to Risley, in carefully corrected or emmetropic eyes the ratio is 3 to 1.

Sursumduction, or the power of uniting the image of the candle flame seen through a prism placed with its base downward before one eye with the image of the same object as seen by the other eye, is ascertained by beginning the trial with a weak prism, $\frac{1}{2}^\circ$ or 1° , and gradually increasing its strength. The limit is usually 3° , but may be as high as 8° or 10° .

If the eyes of the patient under examination are ametropic, the proper

¹The words "power of adduction," etc. are here used with the significance ordinarily attached to them. For another consideration of this matter the student should read the paragraphs relating to the same subject in Dr. Duane's discussion of "The Anomalies of the Ocular Muscles," p. 503.

correcting lenses should be placed before them, and the examination for the various forms of insufficiency made through this glass. It is, moreover, exceedingly important that the correcting glass should be accurately centered; otherwise, in a lens of considerable thickness, a prismatic effect would be produced which would utterly preclude accurate determination of the muscular conditions, especially of the vertical muscles, where the search for fractions of a degree of deviation is sometimes necessary. If the muscular examinations have been undertaken as part of a routine preliminary investigation of an eye, they should be repeated after the refraction has been accurately determined, and, if anomalous, corrected.

Practically, all of the examinations for muscular errors can be made with a series of prisms and a trial frame, but they are facilitated by the use of certain instruments of precision, especially some form of Herschel or *re-*



FIG. 101.—Risley's rotary prism.

volving prism, the one devised by Risley being the best (Fig. 101). The latter consists of two prisms, superimposed with their bases in opposite directions, constituting a total value of 45° . They are mounted in a cell which has a delicately milled edge, and fits in the ordinary trial frame. The milled edge permits convenient turning in the frame, so that the base or apex of the prisms can be readily placed in any desired direction. The prisms are caused to rotate in opposite directions by means of a milled screw-head projecting from the front of the cell. With this rotary prism the strength of the abducting, adducting, and supra- and infraducting muscles can be measured. If the rotary prism is placed before the left eye with the zero mark vertical, and the screw turned to the right or left, it will cause the base of the resulting

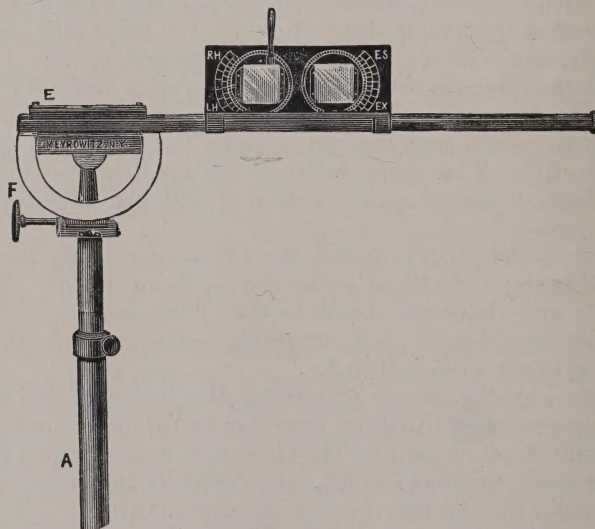


FIG. 102.—Stevens's phorometer.

prism to be either inward or outward, that is, toward the nose or temple, as may be desired; or it may be placed with the zero mark horizontal and the base turned upward or downward. All examinations for muscular defects

may be accurately ascertained with Dr. G. T. Stevens's well-known *phorometer*, which is illustrated in Fig. 102.

One of the simplest tests of the ocular muscles is the *obtuse-angled prism* of Maddox. This is composed of "two weak prisms of 3° , united by their bases. On looking through the line thus formed at a distant plane, two false images of it are seen, one higher and one lower than the real image seen by the other eye, the position of which, to the right or the left of the line between the false images, indicates the equilibrium of the eye. A faint band of light, of the same breadth as the two false images, is seen extended between them" (Fig. 103). The answers of the patient may be materially assisted by placing a red glass before one eye and thus tinting the real image. If this stands directly in the center between the two false images, all forms of insufficiency are eliminated; if it stands to the right or to the left, there is insufficiency of the

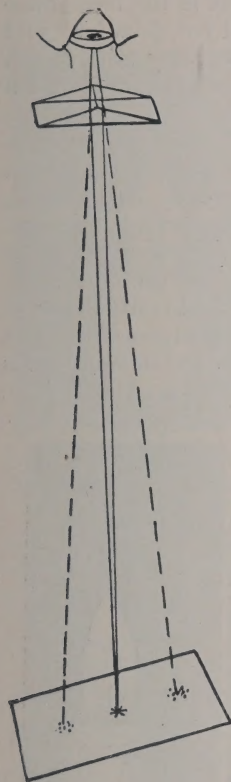


FIG. 103.—Position of the images as seen through the obtuse-angled prism of Maddox (Randall).

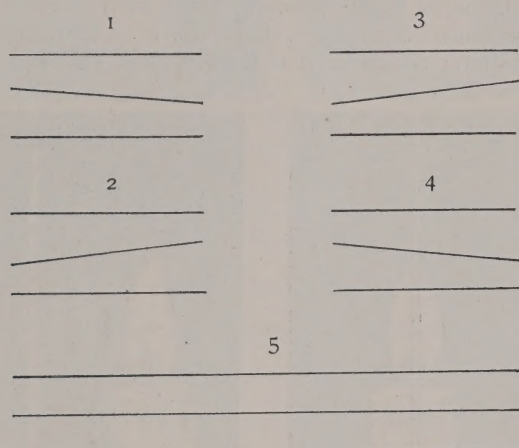


FIG. 104.—Tests for insufficiency of oblique muscles (Savage): 1, insufficiency of left superior oblique; 2, insufficiency of left inferior oblique; 3, insufficiency of right superior oblique; 4, insufficiency of right inferior oblique; 5, equilibrium of oblique muscles.

external or of the internal recti; if it stands above or below the center, or is fused with the upper or the lower image, there is insufficiency of the superior or inferior recti.

Insufficiency of the oblique muscles (cyclophoria), according to Savage, may be detected "by placing a Maddox-prism, with its axis vertical, before one eye (the other being covered), which regards a horizontal line on a card 18 in. distant. This line appears to be two, each parallel with the other. The other eye is now uncovered, and a third line is seen between the other two, with which it should be parallel. Want of harmony in the oblique muscles is shown by want of parallelism of the middle with the other two lines, the right end of the middle line pointing toward the bottom and the left end toward the top line, or *vice versa*, depending upon the nature of the individual case"¹ (Fig. 104).

¹ Much doubt has been cast upon the accuracy of this test by F. B. Eaton, who considers the phenomenon a physiologic one. Consult *Journal of the American Medical Association*, Sept., 1894.

The *rod-test*, also designed by Maddox, depends upon the property of transparent cylinders to cause apparent elongation of an object viewed through them, so that a point of light becomes a line of light so dissimilar from the test-light that the images are not united. It may be suitably employed by having mounted in a cell which will fit in the trial frame a transparent glass rod colored red, $\frac{3}{4}$ in. long, and about the thickness of the ordinary stirring-rod used by chemists, or a series of glass rods placed one above the other (Fig. 105).

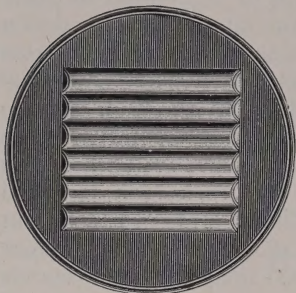


FIG. 105.—Maddox-multiple-rod.

The examination for *horizontal deviation* is thus described: "Seat the patient at 6 m. from a small flame, placed against a dark background, and put the rod horizontally before one eye. If the line passes through the flame, there is orthophoria (equipoise) as far as the horizontal movements of the eyes are concerned. Should the line lie to either side of the flame, as in most people it will, there is either latent convergence or latent divergence; the former, if the line is on the same side as the rod (homonymous diplopia); the latter, if to the other side (crossed diplopia)" (Fig. 106).

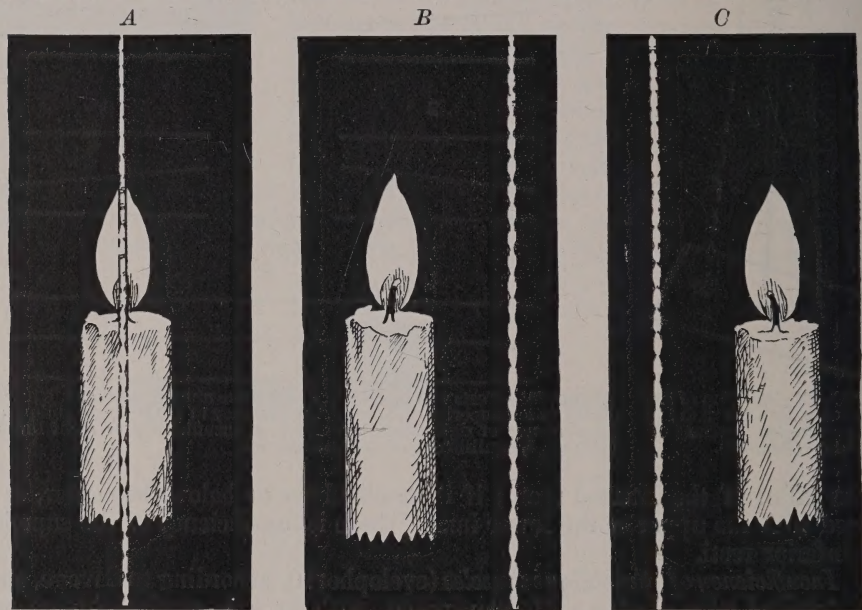


FIG. 106.—Maddox's rod-test for horizontal deviation; the rod is before the right eye: *A*, the line passes through the flame—orthophoria; *B*, the line passes to the right of the flame—latent convergence, or esophoria; *C*, the line passes to the left of the flame—latent divergence, or exophoria.

In order to test the *vertical deviation*, the rod is placed vertically before the eye: a horizontal line of light appears, and the patient is asked if the line passes directly through the flame or if it appears above or below it. The following rule, quoted from Maddox, will suffice to indicate the "hyperphoric" eye: "If the flame is lowest, there is a tendency to upward deviation of the naked eye; if the line is lowest, of the eye before which the rod is placed" ¹ (Fig. 107).

¹ Dr. Swan M. Burnett substitutes for the Maddox-rod a 6 D. cylinder.

The measurement of the extent of the deviation may be made in the ordinary way by finding that prism, placed before the naked eye (preferably with the rotary prism of Risley), which brings the line and flame together.

In order to avoid the awkwardness of the phraseology "insufficiency of the internal recti," etc., and at the same time more accurately to describe the

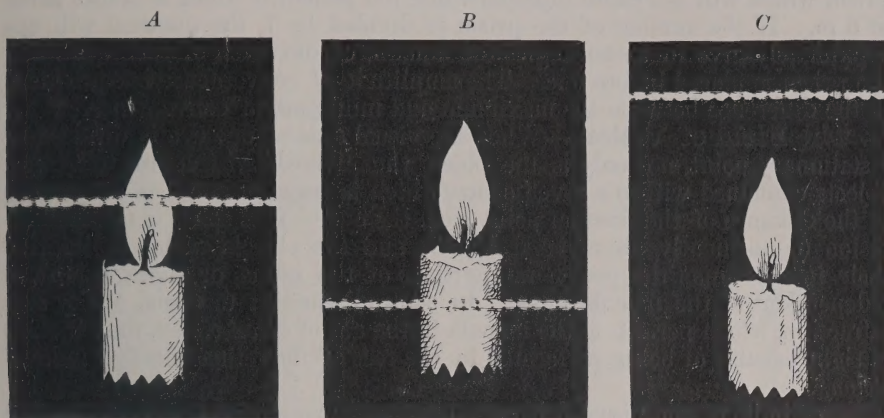


FIG. 107.—Maddox's rod-test for vertical deviation: the rod is before the right eye: *A*, the line passes through the flame—orthophoria; *B*, the line passes below the flame; the upper image belongs to the left eye—right hyperphoria; *C*, the line passes above the flame; the upper image belongs to the right eye—left hyperphoria.

muscular anomalies, the following terminology has been introduced by Dr. George T. Stevens, and has received a deservedly wide acceptance:

The condition in which all adjustments are made by muscles in a state of physiological equilibrium is called *orthophoria*.

Disturbances of equilibrium are known as *heterophoria*, or insufficiencies of the ocular muscles.

The deviating tendencies of heterophoria may exist in as many directions as there are forces to induce irregular tensions.

The following system of terms is applied to the various tendencies of the visual lines:

I. **GENERIC TERMS.**—*Orthophoria*: A tending of the visual lines in parallelism.

Heterophoria: A tending of these lines in some other way.

II. **SPECIFIC TERMS.**—Heterophoria may be divided into—

1. *Esophoria*: A tending of the visual lines inward;

2. *Exophoria*: A tending of the lines outward;

3. *Hyperphoria* (right or left): A tending of the right or left visual line in a direction above its fellow.

This term does not imply that the line to which it is referred is too high, but that it is higher than the other, without indicating which may be at fault.

III. **COMPOUND TERMS.**—Tendencies in oblique directions may be expressed as *hyperesophoria*, a tending upward and inward; or *hyperexophoria*, a tending upward and outward. The designation "right" or "left" must be applied to these terms.

Power of Convergence.—In order to determine the maximum of convergence an instrument known as an *ophthalmo-dynamometer* may be employed. The one devised by Landolt consists of a metallic cylinder, blackened on the outside, placed over a candle flame. The cylinder contains a vertical slit 0.3 mm. wide, covered by ground glass. The luminous vertical line thus produced is the object of fixation. Beneath the cylinder is attached a tape measure graduated on one side in centimeters, and on the other in the corresponding number of meter-angles. The fixation object is gradually approached in the median line toward the patient, until that point where double

vision occurs is reached, or the nearest point (*punctum proximum*) of convergence, and the distance in centimeters read from one side of the tape, and the corresponding maximum of convergence in meter-angles on the other.

The minimum of convergence may also be ascertained with the instrument, but when this is *negative* it is determined by finding the strongest abducting prism which will not cause diplopia while the patient is fixing a candle flame at 6 m. If the number of the prism is divided by 7, the quotient will approximately give in meter-angles the amount of deviation of each eye when the prism is placed before one. The amplitude of convergence is equivalent to the difference between the maximum and minimum of convergence.¹

The Field of Vision.—When the visual axis of one eye is directed to a stationary point, not only is the object thus “fixed” visible, but all other objects contained within a given space, which is large or small in proportion to the distance of the fixation point from the eye. This space is the field of vision (conveniently abbreviated V. F.), and the objects within it imprint their images upon the peripheral portions of the retina, or those which are independent of the macula lutea. In contradistinction to visual acuity and refraction, which pertain to the macula in the act of *direct vision*, the function of sight capable of being performed by the rest of the retina is called *indirect vision*.

The limits of the visual field may be roughly ascertained in the following manner: Place the patient with his back to the source of light, and have him fix the eye under examination, the other being covered, upon the center of the face of the observer, or upon the eye of the observer, which is directly opposite his own at a distance of 2 ft. Then let the surgeon move his fingers in various directions midway between himself and the patient on a plane with his own face, until the limits of indirect vision are determined, controlling at the same time the extent and direction of the movements by his own field of vision. Instead of using fingers as the test-object, the author, in common with many surgeons, is accustomed to employ a black rod 18 in. long, which is capped with an ivory ball 12 mm. in diameter. Colored balls may also be employed in the same way, and a fair idea of indirect color vision obtained.

These methods suffice to discover any considerable limitation of the visual field, but should always be supplemented by a more exact procedure.

If it is desired to have a map of the field not larger than 45° in extent, let the patient be placed 25 cm. from a blackboard, which may be conveniently ruled in squares, and fix the eye under observation upon a small white mark. The observer then moves the test-object, a piece of white paper 1 cm. square, affixed to a black handle, from the periphery toward fixation, until the object is seen. If eight peripheral points are marked and afterward joined by a line, a fair map of the field of vision will be obtained,² which

¹ Landolt's *Refraction and Accommodation of the Eye*.

² The value in degrees of the squares on the blackboard may be ascertained by the following table, provided the eye is placed exactly at 25 cm. from the fixation-point:

2.2 cm.	= 5°	in the	perimeter	semicircle.
4.4 “	= 10°	“	“	“
6.7 “	= 15°	“	“	“
9.1 “	= 20°	“	“	“
11.7 “	= 25°	“	“	“
14.4 “	= 30°	“	“	“
17.5 “	= 35°	“	“	“
21 “	= 40°	“	“	“
25 “	= 45°	“	“	“
30 “	= 50°	“	“	“
36.7 “	= 55°	“	“	“
43.3 “	= 60°	“	“	“

may be transcribed upon a chart, like the one originally suggested by Joy Jeffries (Fig. 108).

In like manner, a *campimeter* may be employed, the one designed by De Wecker being a useful model. It may be understood by reference to Fig. 109. The patient's eye regards the cross in the center of a black vertical

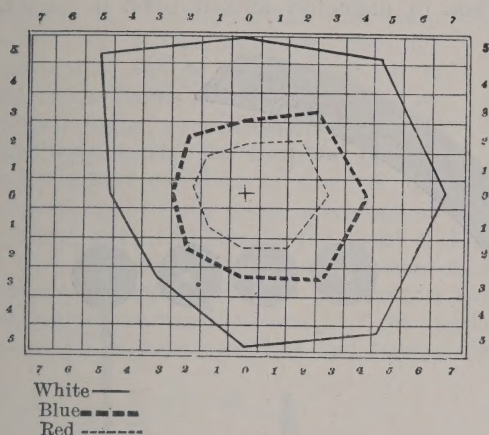


FIG. 108.—Limits of the normal field for white, blue, and red, transcribed upon a blackboard (after Norris).

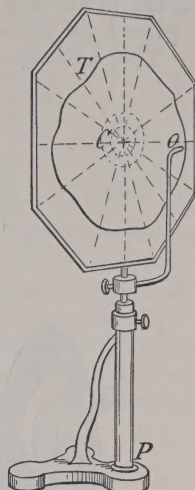


FIG. 109.—Campimeter of De Wecker.

table while the test-object is moved from the periphery toward the center, and the outermost limit of its recognition is marked on the radiating line which it follows. When each line has thus been traversed, the points are joined by a continuous line, and a graphic representation of the visual field results.

The field of vision may also be examined on a flat surface at a greater distance than 25 to 30 cm., after the manner proposed by Bjerrum. The examinations are made at a distance of 2 m. on a large black screen 2 m. in breadth, which can be let down from the ceiling to the floor. At this distance the blind spot (see p. 169), instead of measuring about $2\frac{1}{2}$ cm., as on an ordinary perimeter, measures 20 cm. in diameter, and everything else is in the same proportion. The test-objects used by Bjerrum are small circular disks of ivory fixed on the ends of long dull-black rods. They vary from 10 to 1 mm. in diameter. The examination is begun in the ordinary way at 30 cm. with the 10-mm. disk, and then continued at 2 meters' distance with a 3-mm. disk. In the first case the visual angle approximately is 2° , and in the second $5'$. The normal boundaries in the first instance have been given; in the second they are 35° outward, 30° inward, 28° downward, and 25° upward. The method is valuable for finding sector-shaped defects, irregular limitations, and especially scotomata (see p. 169).¹

Beyond 45° measurements on a flat surface cease to be accurate, because the object is too far away from the eye; rays perpendicular to the visual line

¹ Dr. Charles H. Williams and Dr. William M. Sweet have constructed self-registering electric perimeters in which, for the ordinary test-objects, white and colored, are substituted small disks of suitable size—that is, 1 to $1\frac{1}{2}$ cm. in diameter—illuminated by an electric light behind them.

coming from a peripheral object would be parallel to the blackboard, and could not arise from it or any object passed across its surface.

The accurate investigation of the functions of the periphery of the retina requires the use of an instrument called a *perimeter*, for which we are chiefly indebted to Aubert and Förster. This instrument consists essentially of an arc (or a semicircle) of wood or metal marked in degrees which rotates around a central pivot, which at the same time is the fixing point of the patient's eye, placed 30 cm. distant—*i. e.* at the center of curvature of the perimeter arc. The test-object, 1 or $1\frac{1}{2}$ cm. in diameter, affixed upon a carrier, is

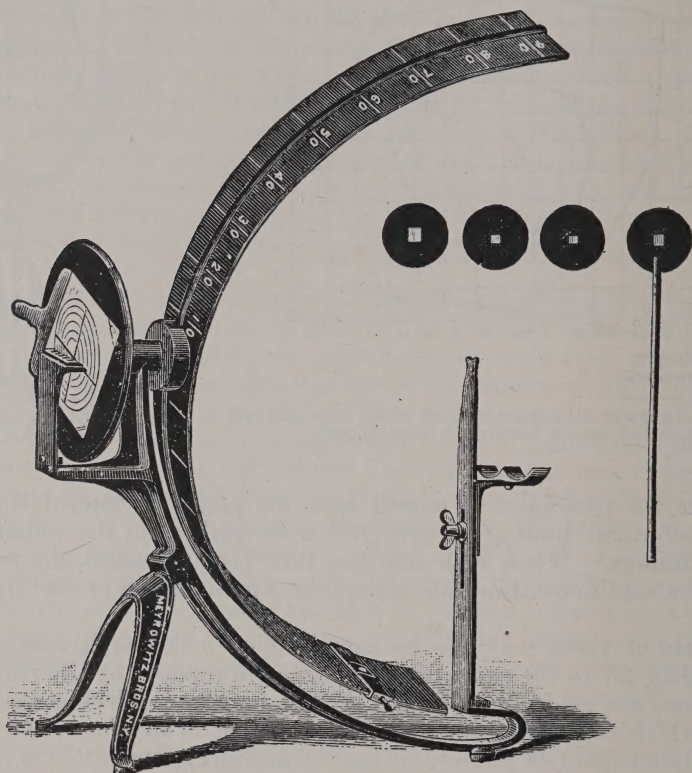


FIG. 110.—Perimeter. The examination may be made with the carrier which moves along the semicircle, or the test-object may be carried along this by means of dark disks attached to a long handle; each disk containing in its center the test-object. The patient's chin is placed in the curved chin-rest; the notched end of the upright bar is brought in contact with the face, directly beneath the eye to be examined, which attentively fixes the center of the semicircle. The other eye should be covered, preferably with a neatly-adjusted bandage. The record-chart is inserted at the back of the instrument, and by means of an ivory vernier the examiner is enabled to mark exactly with a pencil the point on the chart corresponding to the position on the semicircle at which the patient sees the test-object. The various marks are then joined by a continuous line, and a map of the field is obtained.

moved from without inward along the arc, and the point noted in each meridian at intervals of 30° , where it is recognized. Usually the examination is begun with the arc in the horizontal position, which is then moved from this meridian to the next (*e. g.* up and out), and so on until the whole field has been investigated. Generally it is sufficient to examine eight meridians (Fig. 110).

The result is transcribed upon a chart, prepared by having ruled upon it radial lines to correspond to the various positions of the arc, and concentric circles to note the degrees.

The numbering of the meridians on the numerous charts which have been published is far from uniform, as may be seen by examining the accompanying diagrams (Figs. 111, 112, 113). Noyes and Knapp,¹ in order to secure uniform records of the visual field, have advised the designation of the meridians according to the method employed by Helmholtz in his study of the movements of the eye—viz. "to take as the zero point the left end of the horizontal meridian of each eye, and to count from left to right as the hands of a watch viewed by a person under examination move. 0° accordingly marks the temporal end of the horizontal meridian of the left and the nasal end of the same meridian of the right eye; 180° marks the nasal end of the horizontal meridian of the left and the temporal end of the same meridian of the right eye."²

Since the Aubert-Förster instruments appeared the perimeter has undergone numerous modifications and the market is supplied with a host of models. The most practical and time-saving instruments are the so-called

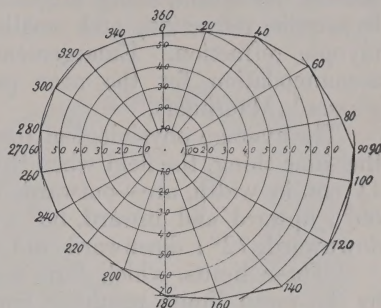


FIG. 111.—Visual-field chart according to Förster.

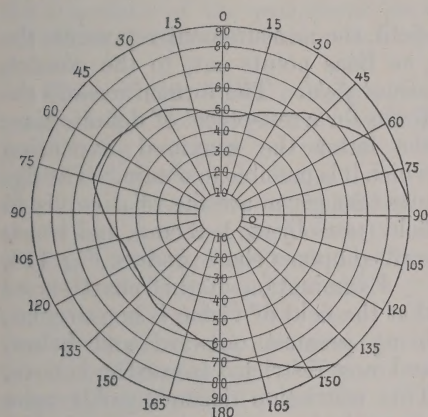


FIG. 112.—Chart for McHardy's registering perimeter.

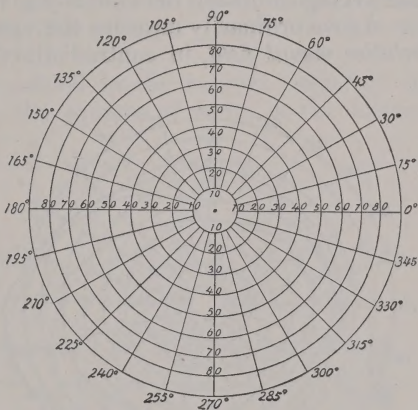


FIG. 113.—Chart for perimeter (Fig. 110).

self-registering perimeters, especially those designed by Stevens, McHardy, and Priestley Smith. A useful model for bedside examinations is the hand perimeter of Schweigger.

The size of the visual field varies considerably within normal limits, being influenced by the character of the light, which should illuminate with equal intensity all portions of the perimeter are in each position; by the size of the test-object, which should be not less than 1 and not greater than 2 cm. in width; by the attention of the patient, whose eye should accurately regard fixation during the measurement; and by the patient's physical and mental condition. Undue prolongation of the examination produces retinal tire and

¹ *Archives of Ophthalmology*, vol. xv. p. 207.

² Instead of having the patient fix his eye upon the central pivot, it may be directed upon a porcelain button on a bar placed 15° from the center to the left if the right eye is to be examined, and *vice versa* if the left is under observation. This plan originally suggested by Förster, makes the optic-nerve entrance, and not the macula, the centre of the visual field.

corresponding contraction of the visual field. The extent of the field of vision is also somewhat under the influence of the size of the pupil and the state of refraction, being larger in eyes with widely dilated pupils or with hyperopic refraction, and smaller in eyes with contracted pupils or with myopic refraction. Enlargement of the visual field may be noted during accommodation for the near point and when the patient wears concave glasses¹ (Mauthner).

The average physiological limits of the *form-field*, or, what is practically the same thing, the field when this has been measured with a square of white $1\frac{1}{2}$ cm. in width, are—outward, 90° ; outward and upward, 70° ; upward, 50° ; upward and inward, 55° ; inward, 60° ; inward and downward, 55° ; downward, 72° ; downward and outward, 85° .

These limits, which form a good working field, are somewhat exceeded by the mean limits resulting from the examination of a number of normal eyes, as recorded by Förster, Landolt, and Baas.¹ The last-named author finds the average result of ten observers as follows: Outward, 99° ; upward, 65° ; inward, 63° ; downward, 76° . Figures indicating a “minimal field,” or “smallest physiological field,” have been recorded, varying from 90° (Förster) to 50° (Treitel) outward; $55\text{--}21^\circ$ upward; $60\text{--}40^\circ$ inward; $70\text{--}40^\circ$ downward. Certainly, in the judgment of the author, the smaller of these limits cannot be regarded as physiological, and the greater is about equal to the average working field already given.

As we ordinarily measure the visual field, the measurement represents the *relative visual field*, in contradistinction, as Baas points out, to the *absolute visual field*. The former records the limits for a test-object of definite size; the latter the maximal expansion which it is possible to obtain. The figures then given are the relative visual field (test-object 1–2 cm.), and transcribed upon a chart produce Fig. 114.

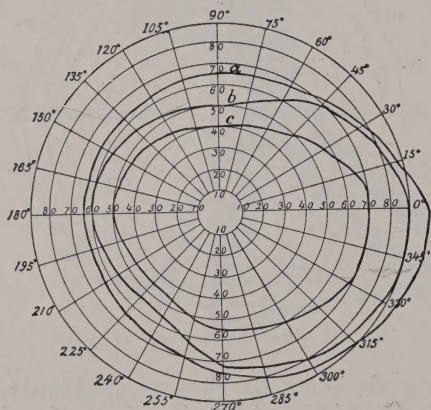


FIG. 114.—Various limits of the form-field: *a*, Baas's average, *b*, average working field; *c*, average least physiological field.

Examination of this chart shows that the field of vision is not circular, being greatest outward and below, and most restricted inward and above. This restriction depends partly upon anatomical reasons—*i. e.* the edge of the orbit, the lids, and the nose interfere with vision, and partly upon physiological reasons—*i. e.* the perceptive layers of the retina extend farther forward on the nasal than on the temporal side, or, as Landolt

expresses it, the outer part of the retina is less used than the inner, and its functions, therefore, are less developed. Hence, as each portion of the field corresponds to the opposite portion of the retina, the inner part is smaller than the outer. To avoid the influence of the physical obstacles afforded by the cranial bones, the eye should be made to fix an object in each meridian 30°

¹ Convex glasses should exercise a contracting influence; indeed, Berlin, quoted by Baas, found a ring-shaped defect in the peripheral visual field if measured through strong convex glasses placed some distance from the eye.

² The ten observers are Baas, Butz, Donders, Drott, Hegg, Landolt, Reich, Schön, Stöber, Treitel. (See Baas: *Das Gesichtsfeld*, Stuttgart, 1896, p. 46.)

in the direction opposite to that under measurement or else suitable rotation of the head should be made.

Binocular Field of Vision.—The field of vision for each eye having been defined, it remains to point out that the field of vision which pertains to the two eyes, or that portion in which binocular vision is possible, constitutes only the area where the central and inner parts overlap. This is evident from the diagram. The continuous line *L* bounds the field of vision of the left eye, and the dotted line *R* the visual field of the right eye. The central white area corresponds to the portion common to both eyes, or to that area in which all objects are seen at the same time with both eyes; the shaded areas correspond to the portions in which binocular vision is wanting. In the middle of the white area lies the fixation point, *f*, and on each side of it the blind spots of the right and left eye, *r* and *l* (Fig. 115).

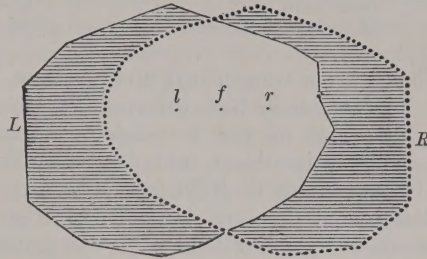


FIG. 115.—Binocular field of vision (Möser).

Having thus determined the *limits* and *continuity* of the visual field, the functions of the peripheral parts of the retina in regard to perception of colors, acuity of vision, and appreciation of light should be investigated.

Color-field.—The color-field is examined in the manner described in connection with the general visual field, the squares of white in the instrument being replaced by pieces of colored paper 1 to 2 cm. in diameter. The order in which the colors are recognized from without inward is—(1) blue, (2) yellow, (3) orange, (4) red, (5) green, (6) violet. In practical work blue, red, and green are the colors employed. Non-saturated colors are not correctly recognized when the test-object is first seen. Thus, yellow at first appears white; orange, yellow; red, brown; green, white, gray, or gray-blue; and violet, blue. The investigation of this zone of imperfect color-perception is important in various pathological conditions, especially in the study of the visual fields of hysteria and of disseminated sclerosis.

The physiological extent of the color-fields, like that of the general field, is subject to variations within normal limits, which are represented by the figures in the following columns. In each left-hand column are the figures denoting the extent of an average color-field mapped with 1 cm. square test-object, while in each right-hand column are the averages of the results of ten observers recorded by Baas, the size of the test-object being 20 mm. in diameter :

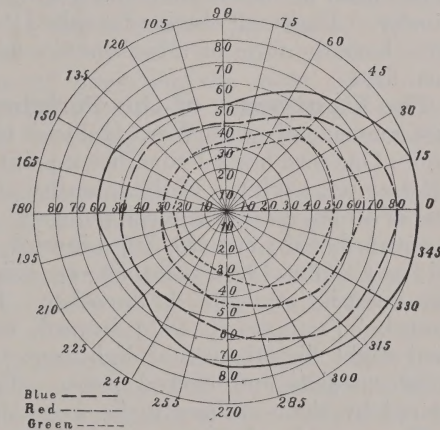


FIG. 116.—Diagram of the field of vision for blue, red, and green : the outer continuous line indicates the limit of the form-field ; the broken lines, the limits of the color-fields.

	Blue.	Red.	Green.
Outward	80-84	65-75	50-65
Outward and upward	60	45	40
Upward	40-45	33-39	27-34
Upward and inward	45	30	25
Inward	45-50	30-39	25-33
Inward and downward	50	35	27
Downward	58-62	45-50	30-43
Downward and outward	75	55	45

These, when transcribed upon a chart, are represented in Fig. 116.

As may have been inferred, the extent of the color-field is greatly governed by the size of the test-object. According to Gowers,¹ who has recently reopened this subject, with a sufficiently large area of color it will be found that all the color-fields differ in extent very little from the fields for white. Green alone seems to fall short of the edge of the white field by about 5°. The extent of the color-field is further governed by the character of the light, the nature and saturation of the color, the contrast in luminous intensity between the colored test-object and the background. To quote from Ward Holden: Other conditions being the same, the field becomes larger as the saturation, the intensity, or the size of the color is increased; and the field is larger the less the contrast in luminous intensity between test-object and background.

The Acuity of Vision of the Peripheral Parts of the Retina.—This diminishes from the macula to the periphery. It may be tested with small squares of black paper, separated from each other by their own width, by noting the point in each meridian where they are recognized as separate objects. The tests of Landolt and Ito are 6, 5, 3, and 2 mm. black quadrants on a white ground. Groenouw employs as a test-object to be passed along the perimeter arc black points on a white ground of $\frac{1}{4}$, $\frac{1}{2}$, 1, 2, and 4 mm. in diameter. The result obtained is called "visual acuteness for a point."² The results have the form of a horizontal oval nearly parallel to the limits of the visual field.

The Light-sense of the Periphery of the Retina.—This may be tested conveniently with Ward Holden's tests, which are thus described by the author: One card has a 1-mm. black point on one side, and a 15-mm. quadrant of light gray, having $\frac{4}{5}$ of the intensity of white, on the other. With a perimeter of 30 cm. radius the black point and gray patch are each seen by a normal eye outward, 45°; upward, 30°; inward, 35°; downward, 35°. The second card has a 3-mm. black point on one side, and a darker gray patch, having $\frac{3}{5}$ the intensity of white, on the other. Each is seen on the perimeter arc, outward, 70°; upward, 45°; inward, 55°; downward, 55°. Card 2 will reveal slight disturbances of light-sense near the periphery, and card 1 in the intermediate and central zones. Groenouw's and Holden's tests are declared by their authors to be more delicate than color-tests, or at least equally so, while they possess the advantage of being more intelligible to the patient.

According to the experiments of Landolt, the perception of light is the most constant function of the healthy retina, and remains nearly the same throughout its surface, while the color- and form-sense rapidly lessen toward the periphery. Progressive diminution of light-sense, however, from center to periphery will be found if test-objects of varying luminous intensity with

¹ *Trans. Ophth. Soc. U. K.*, vol. xv. p. 12. (For further particulars the reader is referred to this most interesting paper.)

² As Baas remarks, the employment of a single point as a test-object affords information not so much of the form-sense as of the light-sense.

the illumination of ordinary daylight are employed. For practical purposes in cases of very defective vision an idea of the retina's sensibility to light may be obtained by passing a candle flame along the arm of the perimeter as a test-object, while a second candle flame is made the point of fixation.¹

The most frequent departures from those limits of the visual field assumed to be normal are general or concentric contraction; contraction limited especially to one or the other side; peripheral defects in the form of re-entering angles; absence of one segment or quadrant; and absence of the entire right or left half of the field (see page 472).

Scotomas.—In addition to these defects, search should be made for dark areas within the limits of the visual field, or *scotomas*. These are distinguished as *positive* when they are perceived by the patient in his visual field, and *negative* when within the confines of a portion of the visual field the image of an external object is not perceived, but the affected area is not discovered until the field is examined. Negative scotomas are further divided into *absolute* and *relative*. Within an absolute scotoma all perception of light is wanting, while within the confines of a relative scotoma the perception of light is merely diminished. The latter are *color scotomas*, usually for red and green. Scotomas are further subdivided, according to their situation and form, into *central*, *paracentral*, *ring*, and *peripheral*.

In every normal eye there is a *physiological scotoma* which may be regarded as the type of an absolute scotoma corresponding to the position of the optic-nerve entrance, which usually may be found 15° to the outer side of and 3° below the point of fixation, the distance from fixation being greater in hyperopic than in myopic eyes. This is known as *Mariotte's blind spot*. Usually the form of the blind spot is not round, but a vertical oval, its upper and lower end being somewhat drawn out to correspond to the larger retinal vessels. Its size depends upon the distance from the cornea. In Landolt's experiments on his own eye at a distance of 35 cm. from the cornea to the plane of projection the mean height of the blind spot was 52 mm. and its breadth 44 mm. The blind spot is much enlarged under certain conditions; for example, by retained marrow-sheath or by papillitis.

For the detection of scotomata small test-objects, white, gray, or colored, $\frac{1}{4}$ cm. square, are employed, which are moved in different directions from the point which the eye under observation attentively fixes, and the spot marked where the object begins to disappear or change its color. The arm of the perimeter is usually marked near the center in half degrees for this purpose. All examinations around the center of the field of vision, and hence the examinations for scotomata, are readily made upon a blackboard. Berry urges that the ordinary test for scotomata be supplemented by making an examination of the particular area of the field at a distance of 2 m. or more, so as to obtain a larger projection of the blind portion, and to be able to work with small retinal images without necessitating the use of very small objects.

Field of Fixation.—This includes all points which the eye under observation can successively fix, the head being perfectly stationary. Various methods for determining the limits of the field of fixation have been employed; for example, watching the image of a candle flame on the center of the cornea

¹ Readers interested in the acuity of vision of the peripheral parts of the retina and tests for the light-sense of the retinal periphery are referred to the excellent papers on this subject by Groenouw (*Archives of Ophthalmology*, xxii., 1893, p. 502); Ward Holden (*Ibid.*, xxiii., 1894, p. 40); and Karl Baas (*loc. cit.*, pp. 52-57). In the last-named publication the literature of the entire subject is reviewed.

as the eye follows the test-light moved along the perimeter arc until the limit of movement is reached. This method, suitable to amblyopic eyes, is not so accurate as one which requires the patient to distinguish letters. The patient is seated before the perimeter, with the semicircle horizontal, precisely as if his visual field was to be examined, and the eye under observation (the head being perfectly rigid) is made to follow a word composed of test-letters representing the minimum acuteness of vision, and the point where vision ceases to be distinct marked in successive meridians.¹ Landolt's measurements of the field of fixation under normal conditions are as follows: Outward, 45–50°; inward, 45°; upward, 35–40°; downward, 60°.

Dr. G. T. Stevens determines the rotations of the eyes with a special instrument called a *tropometer*. According to his measurements, the most favorable rotations are—Outward, 50°; inward, 55°; upward, 33°; downward, 50°. (See also p. 499.)

Tension.—This term indicates the intraocular resistance, and is clinically demonstrable by palpating the globe with the finger-tips. The middle and ring fingers are placed upon the brow of the patient, the tips of the index fingers upon the eyeball, and gentle to-and-fro pressure made, the eyes being directed downward. This pressure must be made in such manner as not to push the ball into the orbit; otherwise no information of its true resistance is obtained. The tension of one eye must always be compared with that of its fellow, and in any doubtful case the results may be contrasted with those obtained by examining an eye known to be normal in another patient of similar age.

Normal tension is expressed by the sign *T_n*, and the departures from it by the symbols +?, +1, +2, +3, and −?, −1, −2, −3: the plus signs indicate increased, and the minus signs decreased, resistance. In physiological experiments various kinds of apparatus, constructed upon the principle of the manometer, are employed, and for clinical purposes instruments known as *tonometers* have been devised. In practical work, however, sufficiently accurate data are obtainable by a careful use of the educated finger-tips.

Proptosis, or protrusion of the eye, may be caused by orbital diseases, tenotomy, paralysis of the ocular muscles, and Graves's disease; while enlargement of the ball is the result of various conditions residing within the globe—myopia, intraocular tumor, and staphyloma. If the cause is unilateral, the resulting condition is asymmetrical and the two eyes may be compared by observing the relative positions of the apices of the cornea with each other and with the line of the brows.

The eyeball is apparently shrunken (*enophthalmos*) in some cases of ptosis and in wasting of the orbital fat, and is diminished in size in high grades of hyperopia and congenital failures of development. As Nettleship has pointed out, the amount of exposed sclera decides the apparent protrusion or recession of the eyeball.

Position of the Eyes.—Instead of presenting parallel visual axes, one eye may be deviated inward, outward, downward, or upward, constituting one of the various types of strabismus, a condition which may or may not be associated with diplopia.

¹ Casey Wood has devised a useful test for this purpose: *Trans. Ophthalmolog. Section A. M. A.*, Chicago, 1896, 252–259.

THE OPHTHALMOSCOPE AND ITS USE; THE NORMAL EYE-GROUND.

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OF PHILADELPHIA.

OPHTHALMOSCOPY is the visual exploration of the eye, and is more strictly limited to the study by transmitted light. Its utilization has inaugurated a new era in ophthalmology, from which most of its scientific development dates; but general medicine has been and is greatly concerned in the information thus gained. The ophthalmoscope ought to be in daily use in the hands of every physician, and it will be when the erroneous impression has been removed that its use is difficult to learn. A half-hour's good instruction can give any intelligent person command of its technique and a dozen illustrations of its various revelations; and moderate practice alone, with loyal adhesion to the cardinal rules, will then serve to widen almost *ad maximum* the field of its employment. Compared with medical microscopy, its technique is very simple, although reasonable persistence in the face of difficulties may be less easy when dealing with a patient than in the quiet conditions of laboratory work. The beginner must not expect to succeed at once under adverse conditions which would try or even baffle the expert: the study of a patient in bed is comparatively hard, even with an electric-light ophthalmoscope, and when intractable or otherwise difficult his examination may prove beyond the power of any one; yet it is to such very practical utilization that the physician may at once unreasonably desire to put the new accomplishment. Restricted at first to easy conditions, the art may be practised with few failures and rapidly growing comprehension; the infinite variations which fall within the physiological limits will be gradually learned and cease to be frequent enigmas, and the physician, made duly self-confident by his success, will not too easily accept defeat when difficulties have to be surmounted. Learning that real cause only need disturb him, he will seek the ground of his difficulties in the narrow group of requirements; and when these have all been met can feel assured that he has located, if not overcome, the obstacles, and learned as much, perhaps, as the circumstances would permit to any one.

The Ophthalmoscope.—The ophthalmoscope, *augen-spiegel* of the Germans, is a mirror for throwing light into the eye. Elaborate and costly forms have been devised in numberless variety, intended to meet almost every possible requirement in the way which the designer thinks best; but it must not be forgotten that any one can in a moment improvise an instrument better adapted sometimes to the needs of the case before him than any which he could find in the shops, and competent for a considerable group of cases. A bit of looking-glass with a hole scratched in its silvering, two or three

microscope-slides held together in the fingers, or three or four cover-glasses in the end of a split stick—improvisations of the original Helmholtz-mirror—can reveal the commencing changes at the macula of renal disease which might easily escape the user of the most high-priced ophthalmoscope. But this “weak-light” instrument is an over-refinement for the majority of cases: the condensed illumination of a perforated concave mirror is more generally useful, and the brow-mirror of the otologist and laryngologist may revert to its earlier use, when Ruete first employed it for ophthalmoscopy.

Yet an instrument designed for wide diversity of ophthalmoscopic work, and convenient in size and construction, is naturally to be preferred. The original ophthalmoscope of Helmholtz is practically unknown to most modern

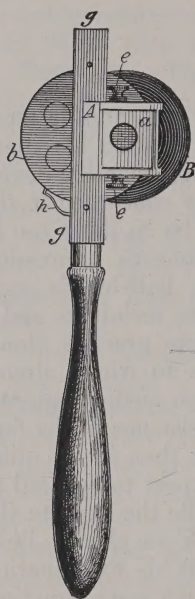


FIG. 117.—Ophthalmoscope of Helmholtz: the concave shade *B* is set at the side of the handle, *a*, with disks of lenses (*b*) centering at its sight-hole. In front of this a triangular case projects, carrying three thin glass plates at an angle of 56° to the line of sight, by means of which the light is reflected into the observed eye.

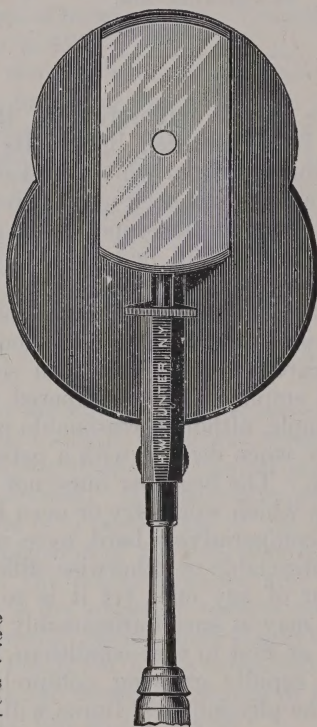
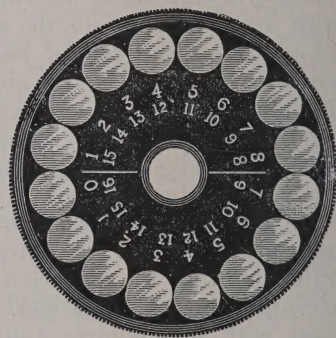
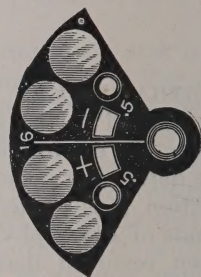


FIG. 118.—Loring's ophthalmoscope, with tilting mirror, complete disk of lenses from -1 to -8 and 0 to $+7$, and supplemental quadrant containing ± 0.5 and ± 16 D. This affords 66 glasses or combinations from $+23$ to -24 D.



oculists, and its surpassing value in some directions has been eclipsed by less cumbersome rivals (Fig. 117). The convex mirror of Zehender, on which the light is concentrated by a lens, has as completely passed away, and almost every ophthalmoscopist of to-day utilizes, with scant or no recognition, the perforated mirror of Ruete. Behind this is generally placed the revolving disk of lenses added by the optician Rekoss—single, double, or even treble—and upon these fundamental elements have been rung changes more numerous than could be here recorded. Some of the best of these arrangements worthy of being credited to the designer we owe to the lamented Dr. Edward G. Loring. The modifications of his later instrument (Fig. 118) are all questionable gains at the cost of undoubted loss, and are almost as numerous as

the individual users. That of the writer (Fig. 119) aims at unusual completeness of the series of lenses, cylindrical as well as spherical, brought *seriatim* to the sight-hole without removing the instrument from the eye, and boasts a minimum deviation from the dimensions, weight, and balance of the best "Loring." Dr. Edward Jackson's admirable use of slides of lenses (Fig. 120) forms the simplest of "refraction-ophthalmoscopes," most warmly to be commended to the non-expert; while Couper's chain of lenses (Fig. 121) or Morton's modification of it offers a most ingenious solution of the difficulty of bringing a wide series of uncombined glasses close behind the sight-hole of the tilted mirror. For the practitioner who is willing to make

but small outlay the simple Liebreich mirror, with its clip to hold its few lenses, will prove fairly satisfactory.

Optical Principles of the Instrument.—These need concern its user little at first. Rule-of-thumb methods will suffice for the great majority of cases, and the minutiae of the dioptries

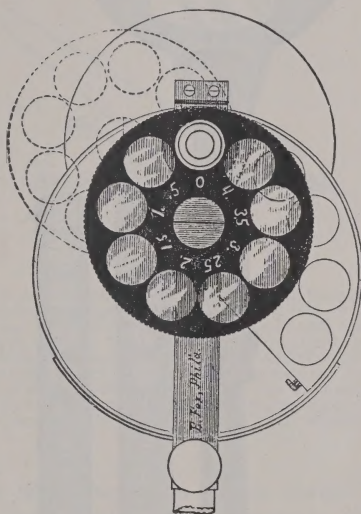
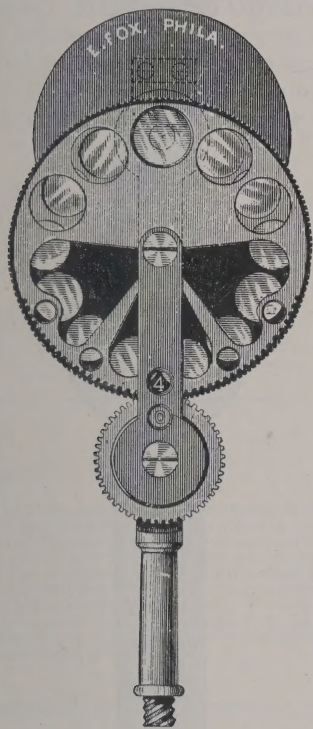


FIG. 119.—Randall's modified Loring ophthalmoscope, in which the "quadrant" is moved by the cog below, so that every glass can be brought to the sight-hole without removing the instrument from the eye. A disk of concave cylinders 0.5 to 4. is excentrically mounted, so that each can be brought at any desired inclination of its axis into combination with any spherical. It gives 51 spherical lenses or combinations. The mirror can be detached to substitute a weak-light, plane, or more concave mirror, or left off, uncovering the 6 mm. breadth of the lenses when the instrument is used as an optometer. The disk of cylinders can be left off as drawn, or attached to any form of ophthalmoscope.

of the eye, upon which depend such questions as the amplification of the erect image and the height or depth of objects, involve formulas from which most oculists shrink. We will consider only the manifest facts, easily observed and verified, which go to make up the possibilities and limitations of the instrument, and will consider the refraction and accommodation of the eye only so far as they force themselves upon the attention of the ophthalmoscopist.

The eye is a camera obscura, provided with a complex lens-system capable of changing focus and armed with a diaphragm—the iris—which varies the size of its central opening—the pupil—limiting the amount of light which enters and the optical imperfections of the image. This pupil generally

appears black because the light entering it is reflected back, after partial absorption, in exactly the direction from which it came. As the observer's head is not generally a source of light, but an obstacle, cutting off all illumination from that direction, his eye receives none of the returning rays. If the pupil be wide, however, and the retinal surface less than the focal distance behind it, as is common in children and in animals, it is not difficult to obtain a red

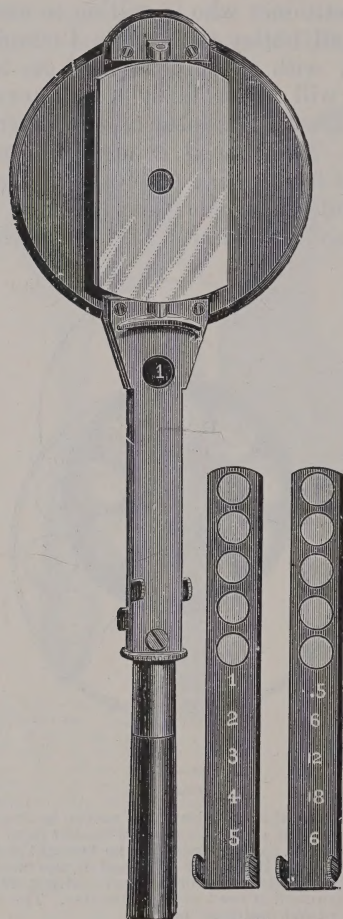


FIG. 120.—Jackson's ophthalmoscope, with two superposed slides of lenses coming singly or combined behind the sight-hole of the tilting mirror. It gives 35 lenses or combinations, from +11 to -18 D., with great convenience, and is exceedingly simple and thin.

Like most other ophthalmoscopes, the figures are red, to indicate concave glasses, and white to mark convex, making mistake or confusion as to combinations unlikely.

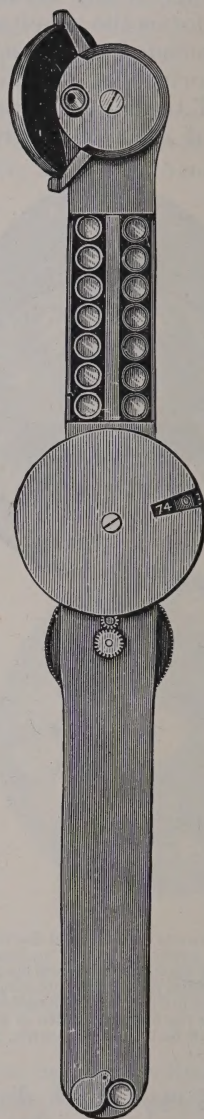


FIG. 121.—Couper's ophthalmoscope, with 74 lenses in endless chain coming singly close behind the excentric tilting mirror, which rotates to the left when the left eye is to be examined. In Morton's modification the lenses are free in the channel, and moved by the sprocket acting below.

reflex from within the eye. Ophthalmoscopy aims to secure uniformly this result, by so reflecting a beam of light that the observer's eye is always in position to receive the returning rays, and not only to obtain a diffused glare from the pupil, but to see numberless details within. For this a number

of optical conditions have to be met, depending not only upon the refraction of the eye in general, but upon that of the observed eye in particular, and involving even the conditions of the observer's eye. To these we first must turn.

By the law of the conjugate foci of lenses, light from within the illuminated eye emerges in parallel rays if the eye be emmetropic, divergent if hyperopic, convergent if it be myopic. To make such rays furnish a clear image of the interior two methods are in vogue, and various optical apparatus is needful for each. The simpler method is known as the "direct," or that of the "upright image," in contrast to the "indirect," which gives an "inverted image."

Direct Method of Ophthalmoscopy.—In this method the mirror is placed before the observer's eye, so as to throw light through the pupil of the observed eye, and the two are brought close together (Fig. 122). If the observed eye be emmetropic, parallel rays pass from it into the observer's, and if this be also emmetropic, a clear image is obtained without further aid. If

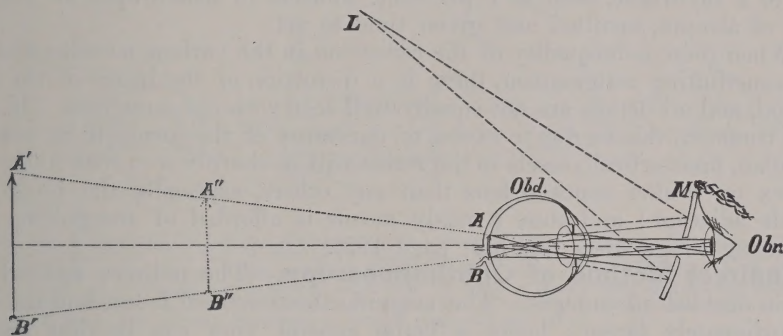


FIG. 122.—Diagram of the direct method with the formation of an upright image: rays from the source of light *L* are received upon the concave mirror *M*, and converged upon the observed eye *Obd.*, within which they cross and illuminate an area of its fundus. From an area *A B* thus lighted, rays pass out of the pupil (parallel if it be emmetropic, as here represented) through the sight-hole of the mirror, and, entering the observer's eye, *Obr.* are focussed upon his retina. An image is there formed as though the object seen were at a great distance, and the perceptive centers project it into space as though the object were at some arbitrary distance (*e. g.* 25 cm.). By the laws of magnification by a simple lens the image is embraced between the lines passing from the optical center of the magnifying-lens (the refracting system of the observed eye), through the extremities of the object, and has the size *A' B'*, *A'' B''*, etc., according to the distance of projection.

the observed eye be hyperopic, myopia or accommodation in the observing eye may neutralize it and permit of seeing clearly; if not exactly thus adjusted, a convex lens must be introduced to render parallel the divergent rays. If, on the contrary, the eye be myopic, the observer must employ a concave glass to bring the convergent rays to parallelism, unless himself hyperopic enough to be focussed for such convergence. Thus it is requisite that there shall be a series of concave and convex lenses at command, which may be skilfully used as required in order to afford clear views in all conditions of refraction.

But this, while inconvenient in some respects, constitutes one of the great advantages of the direct method; for the lens thus required to give a sharp image of the retinal details becomes, under proper conditions, the *measure of the ametropia*. That this should be accurate assumes that the observer must be emmetropic or allow for his error of refraction, and make no accommodative effort that would change it from this basis. The lens thus used must be properly placed before the observed eye. It ought to be about 13 mm. from the cornea, at the anterior focus of the lens-system, and it should be tilted little if

at all, since this has a distorting effect. The ophthalmoscope should be so constructed as to give a considerable series of glasses coming *seriatim* to the sight-hole, which should not be too small nor tunnel-like from thickness of the instrument; and, as the light must be taken from the side of the patient's head, the mirror should incline in the needed direction, leaving the rest of the ophthalmoscope straight.

The field of view open to the direct method is never larger than the pupil, and grows steadily smaller as one draws farther away from the observed eye. So the advantage of a dilated pupil is evident: although an expert can approach so close, locate so well the image presented, and proceeding from it to each other desired part of the eye-ground, can build up from this series of glimpses so satisfactory a mosaic, that he may explore with ease through a 3 mm. pupil when a tyro might find difficulty even were the pupil dilated to 6 or 8 mm. The periphery of the lens and the extremes of the eye-ground cannot be seen through a contracted pupil, however expert the ophthalmoscopist; and a case demanding such study must have a drop or two of a mydriatic, such as 1 per cent. solution of homatropin or 0.5 per cent. of atropin, instilled and given time to act.

When there is inequality of the refraction in the various meridians of the eye, constituting astigmatism, there is a distortion of the image of the eye-ground, and all details are not equally well seen with the same lens. If, as is most common, this be due to excess of curvature of the cornea in its vertical meridian, fine vertical vessels in the retina will be sharply seen with a stronger convex or weaker concave lens than any others, especially the horizontal vessels adjacent; and thus a ready means is afforded of recognizing and measuring astigmatism (see also page 199).

Indirect Method of Ophthalmoscopy.—The indirect method has certain decided advantages. The magnification obtained is less and the field proportionately larger; hence a better general view can be thus gained. Then its sharpness is largely independent of the refraction of the eye, unsteady movements are less disturbing, and it can supplement the direct method in many important relations. Differences of level count for less, although quite perceptible, and may reveal their true relief, previously misunderstood.¹ A simpler instrument is competent, since a concave mirror, a double convex lens of 2–3 inches focus (14–20 D.), and one or two lenses to clip behind the sight-hole meet all requirements.

In this method the eye is illuminated from a distance of 25–30 cm., and the emerging rays, unless already strongly convergent, are intercepted with the convex lens held some 5 cm. in front, so that they are brought to a focus near by. Here a real inverted image is formed in the air (Fig. 123), and this, and not the eye-ground itself, is studied by the observer, generally with the help of a convex lens to magnify it. The principle is the same as that of the compound microscope, while the direct method is like the use of a simple lens, the lens-system of the observed eye serving to magnify all the details of its own interior. The myopic observer may often dispense with any magnifier back of his mirror, and if the observed eye be very myopic, it forms the requisite image near enough in front to obviate the need for an object-glass. Here, then, the mere concave mirror may serve all needs, and in circumstances where the satisfactory use of the direct method is very difficult.

In this method much depends upon the clearness of the object-lens held near the observed eye; and one of ample size and of material, like pebble,

¹ The cupping of glaucoma was mistaken for prominence by the earlier observers.

not easily scratched, has distinct advantage. A protecting mounting is often useful. The reflection from the pole of the cornea is less troublesome than when contrasted with the weaker illumination of the direct method; but the reflections from the front and back surfaces of the objective lens compel a little tilting of it to throw them out of the way.

An element of astigmatic distortion is thus introduced which must be allowed for. A round optic disk may be made to appear oval, the longer diameter corresponding with the least inclined diameter of the lens. When the eye is astigmatic a similar distortion of the disk appears, which may be modified by tilting the lens; but irrespective of this, to-and-fro movement of the lens corrects and reverses the apparent lengthening of the nerve-head, which reveals whether it is anatomically or only optically elongated.

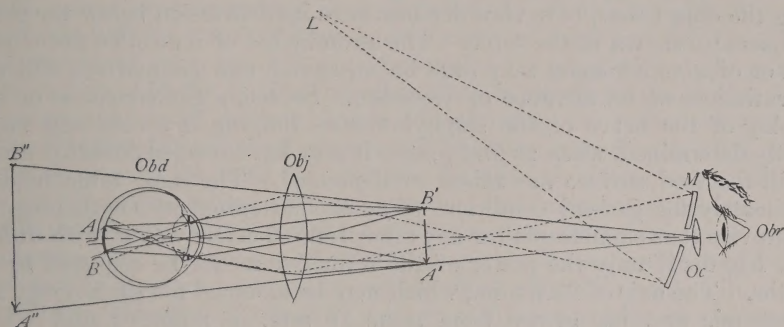


FIG. 123.—Diagram of the indirect method giving an inverted image: rays from the source of light *L*, converged toward the observed eye *Obd* by the concave mirror *M*, are intercepted by the lens *Obj*, and after coming to a focus diverge again and light up the fundus. From a part of the illuminated fundus *AB* rays pass out of the pupil to be again intercepted by the lens *O* and form an inverted real image at its anterior focus *A' B'*. This real image is viewed by the observer's eye behind the sight-hole of the mirror with the aid of a magnifying-lens *Oc*, and is seen enlarged, as at *A'' B''*.

Size of the Image and Mensuration of Fundus-Details.—The problems as to the amplifications afforded by the upright and by the inverted image and the mensuration of objects in the fundus are complex and variable. Even in the “reduced eye” many other factors must be determined in order to permit of precise statement of the result. Suffice it here to say that in the emmetropic eye the upright image, when projected to 10 inches, is about sixteen-fold the linear size of the retinal surface seen; and an optic disk 1.5 mm. in diameter will seem 24 mm. broad when projected to 25 cm. An easy test of this is to hold a quarter-dollar or shilling before the one eye while the other views the disk, and find the point where the images seem of equal size: this distance will vary little from 10 inches. In hyperopia the enlargement is less, in myopia more, the myopic eye having virtually an extra magnifying lens in it as contrasted with the emmetropic, and still more the hyperopic. The indirect method affords about one-third as much amplification as the direct, increasing as the object-glass is weakened and the ocular strengthened. Hence myopia gives smaller and hyperopia larger images by this method.

Another interesting point, still more practical, is the mensuration of the axial lengthening or shortening as afforded by prominences or depressions of the eye-ground. Having determined the refraction at the general retinal level, the ability (aside from astigmatic conditions) to see some object with stronger convex or weaker concave lenses marks its protrusion above that level, and the following table shows the amount of elevation calculated for the “reduced emmetropic eye:”

Lengthening or Shortening of the Eye in Axial Ametropia (Landolt).

Myopia.	Increase.	Axial length.	Hyperopia.	Decrease.	Axial length.
0	0	22.824	0	0	22.824
0.5	0.16	22.98	0.5	0.16	22.67
1	0.32	23.14	1	0.31	22.51
2	0.66	23.48	2	0.62	22.20
3	1.01	23.83	3	0.92	21.90
4	1.37	24.19	4	1.21	21.61
5	1.74	24.56	5	1.50	21.32
7	2.52	25.34	6	1.76	21.06
10	3.80	26.62	7	2.03	20.79
15	6.28	29.10	8	2.28	20.54
20	9.31	32.13	10	2.78	20.04

On the contrary, the need of stronger concave or weaker convex lenses to bring the object sharply to view demonstrates its depression below the general level, as also shown in the table. The prominence of a swollen optic nerve-head or of a tumor-mass may thus be measured, and comparison will show the variations of its advance or recession. So, too, a glaucomatous or other cupping of the nerve or the staphylomatous bulging in a coloboma may be exactly determined, when at first glance it may have seemed doubtful whether the ill-focussed surface was raised or depressed. The same table holds approximately for general conditions of axial shortening or lengthening, with the proviso that emmetropia (or any other refraction) may exist with different axial lengths if only the power of the refractive media be adjusted to such lengths. The axis of 23.8 mm., which may be assumed for the average adult emmetropic eye, has grown from some 16 mm. in infancy; and while a diopter or so of congenital hyperopia may possibly have been outgrown, the eye may be said to have changed its length and its refraction exactly *pari passu*.¹ As the other diameters of the globe are generally approximately the same as the axis, and the corneal diameter is about one-half as great, a correction can be thus gained, perhaps, when in an eye not showing typically myopic or hyperopic deformity we wish to estimate from the refraction its exact length and the position of objects not on the retinal level within, as may be desired in case of operation for the removal of a foreign body in the vitreous. (See also page 201.)

The mensuration of objects or distances on or near the retinal level can generally best be given in terms of the cardinal objects there presented for comparison—*e. g.* “broad as the retinal vein,” “two disk-diameters out,” etc. The actual size can easily be then estimated with as close approximation as would be possible with the complicated apparatus devised for actual measurement.

Examination of the Media.—Previous to the employment of either method of examination of the fundus it is generally advisable to investigate the media lying in front of it both by *focussed incident light* (oblique illumination, see page 146) and by *transmitted light*.

For the latter it suffices to illuminate the eye with the concave mirror from eight or ten inches away, when any opacity in cornea, lens, or vitreous will appear as a dark silhouette against the reddish background. Magnification of this by a convex lens behind the mirror enhances the delicacy of the test, and often brings to view minute details otherwise invisible. Beginning at some 25 cm. away with a + 4 D. lens, the surgeon can study each eye, both looking straight forward and in oblique positions; and then, approaching closer and using stronger lenses, he can focus at will upon the cornea, lens-

¹ Randall: *Trans. Amer. Ophth. Soc.*, v. 1890, p. 657.

layers, anterior or posterior capsule, or the various depths of the vitreous, until at the closest range the strongest available amplification may be utilized. Foreign bodies escaping every other effort at their detection are thus readily seen, and opacities or vascularities of the cornea form striking objects.

The preliminary observation from a distance has a great advantage also in the determination of refractive errors, for little or no eye-ground detail comes sharply to view, except in hyperopia or marked myopia: in the latter, slight movement of the eye or head will show that the image is inverted. Irregularities of refraction also become thus readily manifest, flattened facets left by loss of substance appearing like blisters in a window-pane to distort the details seen through them and give the image as in high hyperopia. The condition known as *conicity of the cornea or lens* may thus appear to give a dark center or surrounding zone, although the tissues be perfectly transparent; and if the observer draw back a meter or more and use a long-focus or plane mirror, every eye will give shadows in the pupil with slight rotations of the mirror, and the method becomes what is known as the *shadow-test* or *retinoscopy*, our most delicate means of estimating the refraction (see page 202). Notable differences of eye-ground level are conspicuous when studied from a distance of 20 or 30 cm., and this constitutes the best way of studying detachments of the retina, vitreous opacities, and intraocular tumors.

Admirable, too, is this method for learning the *position of opacities*, since the movements of the eye are about a fixed center of rotation back of the posterior pole of the lens; and every visible object anterior to this will seem to move in the direction of the gaze, and everything posterior in the opposite direction, the rapidity and extent of the excursion indicating by parallax its distance from that center.

Auto-ophthalmoscopy.—A word may also be said as to auto-ophthalmoscopy, although its value is limited. Several methods may be employed, but the simplest is that of Coccius, to hold the plane skiascopy-mirror between the eye and the shaded light, so that the light falls into the pupil through the ample sight-hole, while the emergent rays are caught by the margin of the opening and reflected back to the macula (Fig. 124). Upon the

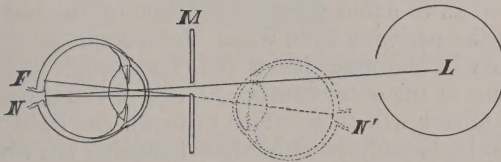


FIG. 124.—To illustrate auto-ophthalmoscopy.

dark background behind the lamp the observer will then project the image of the small illuminated area, and with a little care the disk can be found and studied and the vessels followed out a long way in any direction except close to the macula. The picture is not a mere suggestion, like the Purkinje image, but can be drawn in good detail; and he who is working up eye-ground sketches, and has no other model at hand, can thus often freshen his impressions of form or color at the moment when he most needs them. The inability to see the macular vessels is compensated by the endoscopic methods of bringing them into view (Fig. 134), either by the convex mirror of Ayres or the pin-hole of Mandelstamm.

Illumination is, first and last, the most important element of success in all these measures. A steady and ample source of light of fairly uniform

color is therefore essential. Daylight is undoubtedly the truest illumination under which to study conditions where faint gradations of color are at times all-important; yet even within the hours when it is obtainable it varies greatly in any consultation room. Its use may be ignored except as a matter of curiosity or in some leukemic conditions, when it may be noteworthy if the fundus looks as yellow under it as the normal eye does by lamplight.

An Argand gas-burner, so mounted upon a hinged bracket or an adjustable stand that it may be shifted to any desirable position, is almost always obtainable or may be substituted by any good oil lamp. A second chimney, of glass or isinglass, will shut off much radiant heat from the observer, and still more from the patient nearer by; while an opaque chimney of iron or asbestos with a vertically oval opening about 3 to 5 cm. will be found useful in restricting the light to the desired direction, leaving everything else in shadow. With this precaution the ophthalmoscopic room need not be very dark, although strong rays of daylight should be excluded by shutters or shades; and it is very well to have several blackish surfaces conveniently placed to form fixation points for the patient's gaze during examination. The eyes may be thus kept steady, while the dark surface affords nothing to call forth accommodative strain or pupillary contraction. Either of these may prove serious obstacles to some of our measures, and it is worthy of much care to avoid them.

The test and glare are trying even to well eyes, and must be mercifully and judiciously tempered for over-sensitive cases if we would obtain full success and avoid actual injury. Here the use of the plane or weak-light mirror may have decided value, or the reduction of the light by turning it down or narrowing the aperture through which it shines. If gas-fixtures are used, it is very desirable to so arrange them that the light may be near the patient or the observer as desired, and with a range of 4 to 6 m. for skiascopy—a need best met by having a bracket at each end of the room, one being also used for illumination of the test-type. It is inadvisable to have the light too close to the patient, and much heat reflected by the mirror and directly radiated from the flame may be spared him by putting the burner a foot or more back of his head. It is important, too, that the light shall be as nearly as possible behind the head, so as to avoid needless rotation of the mirror; but it must not be cut off by the patient's head when the macula or temporal retina is being studied. It will be found that if it is far enough to the side to illuminate the lid-margins at the outer canthus, it will meet all conditions. Moderate tilting of the mirror will then suffice to throw the light into the eye, and the instrument can be brought so close that it touches the brow and eyelashes of the patient without having the light cut off.

Position of Surgeon and Patient.—One of the cardinal errors of the beginner is in not getting close enough: the field of view is thus restricted, the corneal reflex more disturbing, and refractive errors unduly distorting or blurring to the details. In highly ametropic eyes great differences in the required lens depend upon its distance from the anterior focal point of the eye—some 13 mm. from the corneal pole; and in high myopia a satisfactory view can sometimes be obtained only when the observer's brow is actually touching that of the patient. This presupposes the condition, essential in most cases, that the observer use his right eye for the patient's right and hold the ophthalmoscope in his right hand, and *vice versa*.

The convenience, or even the possibility, of doing this depends in part upon the seating of patient and observer, and the face-to-face position usual abroad is not at all the best. It is better that the observer's chair should be

close beside the patient's, with the seats fully overlapping; and then, unless very discrepant in height, each may sit erect and at ease. A child is often of better height standing by the ophthalmoscopist's seat, and, on the other hand, satisfactory studies can be most hastily made when the observer stands by the sitting or standing patient. If the light be on a swinging bracket, it can be instantly swung from one side to the other, while the ophthalmoscopist transfers himself and his seat to that side for the study of that eye. Each will learn the position most satisfactory to himself, and habitually adopt it, but a constrained pose is to be deprecated as imperilling accuracy and thoroughness. Children often tend to nod forward if quiet, or, on the contrary, to wriggle and turn, so as to need some steadying: the free hand may do good service, therefore, in lightly grasping the occiput, while the thumb rests in the concha, controlling any rotation (Figs. 125, 126).

Limited by the pupil into which it is thrown, the beam of light utilized



FIG. 125.—Position of examiner and patient for direct ophthalmoscopy, with seats overlapping and brows almost in contact. The right hand and eye are used in examining the right eye of the patient, and the lamp must be on the same side (De Schweinitz).

in the direct method is that from a portion of the mirror close around the sight-hole, and but little larger than the pupil. This must be quite accurately centered with the pupil, as is sometimes best done by throwing the light from a little distance upon the cheek, when the dark center of the illuminated area marking the sight-hole can be seen, and this then centered in the pupil. At the bedside a light with a lens giving a parallel beam is useful. If a candle only be available, inclination of this gives a broader flame and a less limited area of light on the retina.

Three *principal obstacles* are met in the study of the interior of the eye: *reflections*, *opacities*, and *refractive errors*.

Reflections.—To the beginner these are very annoying. He hardly ever approaches sufficiently close to the eye, his fundus-illumination is rarely the best, and the brilliant *corneal reflex* seems to occupy most of the pupillary space, and frequently is regarded as the whitish optic disk for which he is instructed first to look. In a narrow pupil this reflection from the cornea (and to an

extent generally unperceived those also from the front and back surfaces of the lens) is ever an obstacle which the expert cannot wholly ignore, and may at times find insurmountable. Generally he can look to the inner side of it or through its margin, and approach so near that its perception is slight. A small sight-hole also reduces its annoyance by increasing the fundus-illumination and cutting off some of the rays reflected from the cornea.

Reflections are present at all the boundaries between the media, but only those upon the retina are apt to be noticed when not specially sought. In childhood, particularly, the whole retina is often covered, especially along the larger vessels, with shimmering, "*watered-silk*" reflections, which shift with each motion of the mirror, and by the reversed direction of their movement show that they are formed by concave surfaces where the prominence over the vessels passes into the general retinal level. Of the same nature is the more definite *reflex-streak* parallel to the nasal side of the disk, to which



FIG. 126.—Position of examiner and patient for indirect ophthalmoscopy: the seating can be the same as for the direct method, but the examiner sits a foot or more away, holds the object-lens at about its focal distance in front of the observed eye, steadying it by resting the other fingers on the face, and can use the same eye and hand, without change of the lamp, to examine either eye of the patient (De Schweinitz).

Weiss has called attention as being prodromal of myopia (see page 187, Fig. 132), and the bright streak (so-called *light-reflex*) always to be seen along the retinal vessels, especially the arteries, has been thus explained.

In the macular region a *halo* can often be seen by the indirect method, generally horizontally oval, and having a diameter two or more times that of the disk. This is less easily seen in the upright image, unless a strongly concave mirror be used; and unless the ring of reflecting mirror just around the sight-hole be centered exactly with the pupil, only a portion of it will be visible. So, too, as to the little reflection from the *fovea centralis*, which is apt to be crescentic or comma-shaped unless the mirror is exactly centered. Then the tiny concavity reflects the entire ring of brightness surrounding the sight-hole, while the center of its floor gives back a central point of light. Like most retinal reflections, these are best seen when the surface is a little beyond the focus, and are more apt to aid than disturb, since they serve to locate the points deserving minute scrutiny, and are lost as the retinal structures are precisely focussed.

Opacities of the Media.—These are at times prohibitory of study of what lies beyond them, and unless their presence and character be perceived they may prove very harassing or misleading by suggesting partial obscuration of the fundus details, retinal lesions, or refractive errors. But due employment of focal illumination and the lighting of the fundus from a little distance will rarely fail to reveal the real difficulty and serve to locate it exactly. Against the red field of the illuminated pupil every such opacity will show dark in proportion to its lack of transparency; with a magnifying lens behind the mirror most minute and faint objects may be discerned readily. Not only real opacities, but also irregularities of surface, such as conicity of the cornea or lens, flattened facets, or plications as of the capsule, can be thus revealed, and the resultant impairment of vision correctly interpreted. Most difficult of all are the cases of turbidity of the media, since there are often no formed elements to give definition to the opacity, which merely obscures the view. Where the aqueous humor is at fault the altered appearance of the iris often furnishes the clue; but a discolored lens or a turbid vitreous can at times puzzle the most expert and permit of diagnosis only by exclusion.

Location of Opacities.—This is of frequent importance. When far back near the retina the anterior position of opacities can generally be appreciated, if not estimated, by parallax, as compared with the movement of the retinal vessels; but the expert easily measures in the erect image by the interposition of convex lenses how much forward an object lies. Near emmetropia each diopter gives a difference of 0.3 mm.—theoretically increasing to the myopic side, decreasing in hyperopia (*e. g.* + 6 D. = 1.77 mm.; - 6 D. = 2.13 mm., Nagel). Anterior opacities, on the other hand, are generally referred to the pupillary margin, and by their motion relative to it in movements of the eye their distance back or front is determined. The center of corneal curvature, which is near the posterior pole of the lens, may also be used, as pointed out by Jackson: the image of the mirror can always be seen in the line of this point, and any motion in reference to it determined. As previously stated, the rotation-center of the globe is the cardinal point of reference (p. 179).

Refractive Errors.—These can markedly complicate the diagnosis if the observer be not well posted. It is often surprising how much can be discerned in an unfocussed eye-ground, not only when hyperopia allows a clear view of details from a distance or to an observer who does not relax his accommodation, but even when considerable myopia or astigmatism precludes sharpness of definition. To the indirect method these cases offer small difficulty: moving the objective lens a little to or from the eye compensates for large axial variations, while a little tilting of it makes or corrects astigmatism as great as is often met. Yet even to the direct method more is revealed than might be expected, and careful focussing is called for to decide whether all the distortion or blur present is really due to the refractive error. Much anatomical anomaly or pathological lesion can be concealed by the imperfection of the view; and minor changes in nerve, choroid, and retina are thus habitually passed over unseen or ignored by ophthalmoscopists of long experience. The habit of sketching the findings in the examinations has here one of its prime functions; and the use of stereotyped forms on which to fill in details is to be condemned, at least for the beginner. Each drawing, however rude and imperfect, should portray with all possible precision the apparent form of the disk, the trend of its vessels, and the conditions of its margins; since the minute observation here called for may prove unexpectedly valuable in these very cases, and begets an exactness of perception essential

and invaluable both in refraction-measurement and in the clinical observation of diseased conditions.

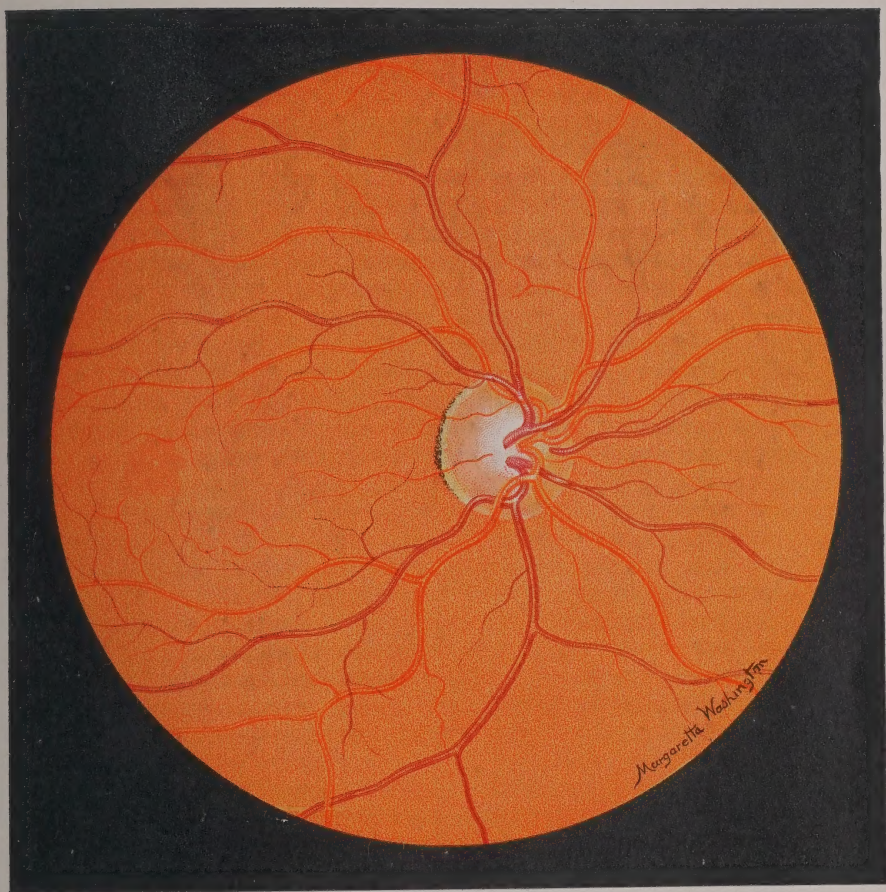
Differences of Level in the Eye-ground.—These are always to be expected. The normal disk has a prominence which justifies its name of *papilla*, although its center is often excavated nearly to the level of the *cribriform lamina*. The excentric location of the disk commonly exaggerates the greater protrusion of the nasal side, and its major vessels are decidedly prominent. This prominence may be much increased by edema and inflammatory infiltration, while the lower level of the outer margin and adjacent posterior pole grows deeper with the atrophic changes and stretching of "posterior staphyloma." This phrase, like that of "conus," is often employed as to conditions not strictly fulfilling its primary meaning; but the opposite view, that bulging at this point due to inflammatory softening does not take place, meets daily refutation. These points must always be taken into consideration, not only in relation to the present refraction of the eye, but also as to its past and future.

In the direct examination, then, we measure the direction of the rays of light, which, emerging from the observed eye, form a sharp image on the observer's retina. But this relation is affected by the observer's refraction as well as the patient's. Only upon an emmetropic eye will parallel rays be exactly focussed; and any interposed lens needed to make sharp the image measures the momentary ametropia of the patient $\pm$ that of the observer. But it is only the refraction at the moment which is measured, and this may be very far from the static refraction which we desire. The ophthalmoscopist must learn what is his true static refraction, and as far as possible relax always to this condition. The author believes every one can learn so to do, although fatigue, headache, or improper conditions will at times preclude utilization of the faculty. If the examiner does not, any fixed allowance for his unrelaxed accommodation is so utterly vague as to be of little value. Those who habitually use mydriatics to the total paralysis of accommodation, and accept in their measurements nothing as "near enough" to right which can possibly be improved upon, learn that total relaxation and total paralysis are identical in almost all cases, and that the "tone" of accommodation of which Donders wrote decreases under scrutiny to the vanishing-point.

The Normal Fundus.—The prime feature and landmark of the eye-ground is the *nerve-head*, with its branching central artery and vein. This lies some 15° to the nasal side, and a little higher than the posterior pole of the globe, and appears as a whitish disk from which the vessels ramify in the fundus (Fig. 127). It is surrounded by the red choroid, which usually defines sharply its margin; and the frequent massing of choroid pigment here may give a gray or black edge, which is occasionally half as broad as the disk. The opening through the choroid is normally smaller than that of the sclera, and hides all trace of this; but at times, without recognizable absorption of the choroid or its pigment, a ring of white scleral tissue (*scleral ring*) can be seen, partial or complete, within the *choroidal ring*. (See Plate 1.)

Consisting of the nerve-fibers which enter to the retinal level and then disperse, the disk often presents a slight prominence or *papilla*, in the center of which the diverging tissues form a *porus opticus*. This may be inconspicuous, especially in early life; but is at times both wide and deep, one edge or perhaps all steep or overhanging, while part of it is usually shelving. The most conspicuous feature is the group of branching vessels. Both artery and vein may come to the summit of the papilla before dividing, but commonly both branch in the bottom of the *porus*, while occasionally only the

PLATE 1.



The normal fundus.

subdivisions in bewildering number emerge from the nerve-head. Little difficulty should be experienced in distinguishing the broader, darker veins with their crimson tint from the scarlet arteries, which are near the color of the background; but the smaller branches differ less until they cease to be differentiable. On the larger veins and on all the arteries distinguishable as such, a bright streak of reflection ("*light-reflex*") marks the central convexity and shifts slightly with variations of the light.

The branching is usually dichotomous, giving an upper and a lower artery, which again divides into a temporal and a nasal branch, while the veins

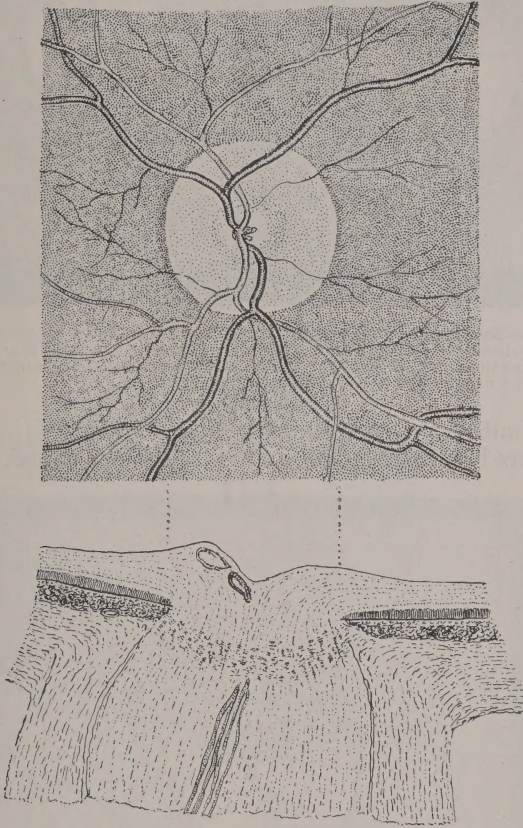
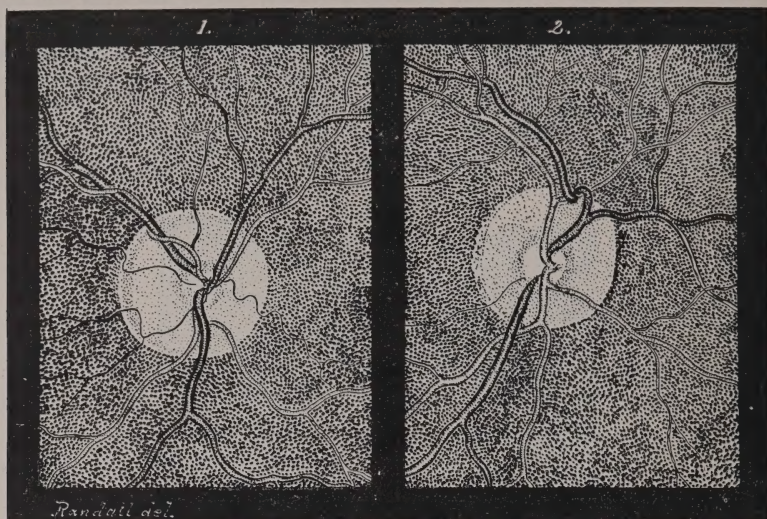


FIG. 127.—Normal optic nerve-head, as seen with the ophthalmoscope and in section under the microscope, each $\times 15$ diameters. The slight papillary elevation, with its central porus, the central vessels, and the beginning of their ramification in the fiber-layer of the retina, the sharp-cut margin of retinal and choroidal pigmentation outlining the disk and slightly emphasized as a choroid ring, are well shown.

present fair parallelism. Small vessels, not always visibly arising from the central, generally pass outward toward the macula; and at this margin especially, independent *cilio-retinal vessels*, not always of small size, are frequently met. The branches pass from the disk with sinuous curving sweep, as a rule, and with slowly diminishing caliber extend toward the periphery. On the disk, especially as they curve down into the excavation, the veins often present visible pulsation, and in rarer cases of disproportionate pressure the arteries also empty and fill, particularly in glaucoma; crossing and entwining of vein and artery are common (Figs. 128, 129), but it is extremely rare for

vein to cross vein, or artery artery. Anastomosis of the vessels, almost always on the disk, is also of the rarest occurrence (Fig. 130).



FIGS. 128 and 129.—Entwined retinal vessels. Twisting of a retinal vein around the accompanying artery on their way to the region supplied is not unusual—generally about the margin of the disk: such a course of an artery, as the superior temporal in (1), is rarer, as is also the recurrent turn of the upper temporal vein to twist around the upper nasal artery in (2).

The rear limit of the nerve-head is the *cribriform lamina*, at which the optic nerve-fibers lose their sheaths and enter the eye as naked axis-cylinders.



FIG. 130.—Anastomosing veins and aberrant artery.

This varies in depth, but can generally be distinguished, especially at the porus; and a deep excavation generally has as its bottom this mottled sieve-tissue.

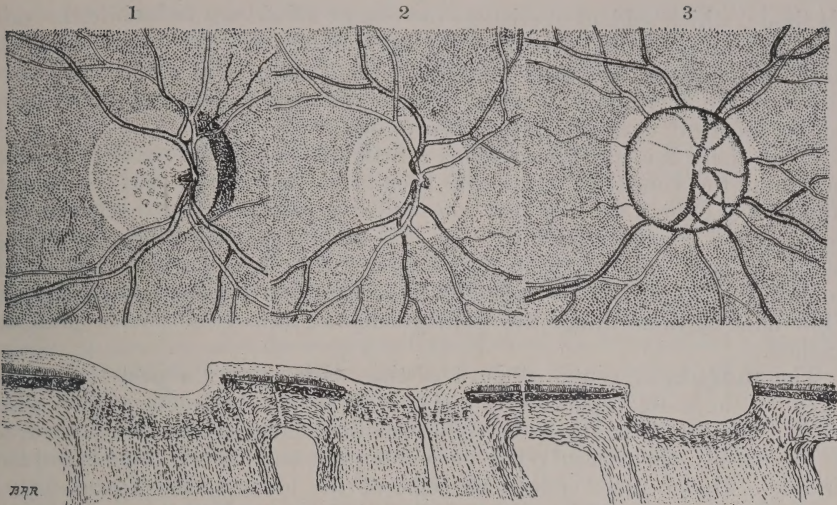
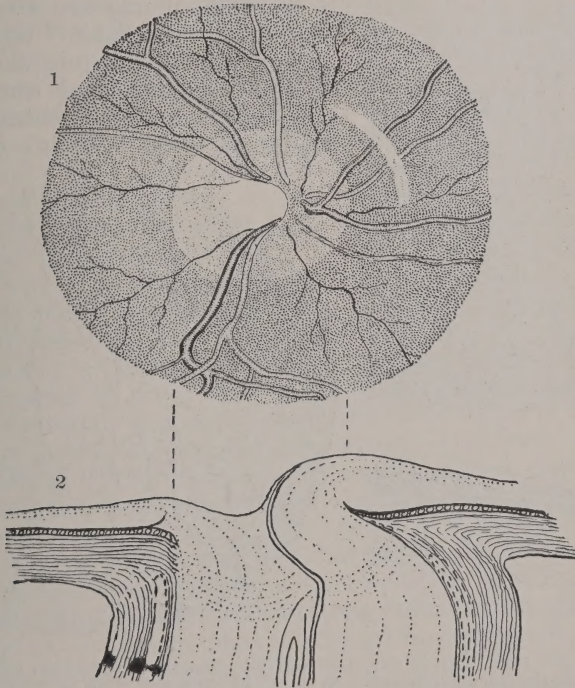


FIG. 131.—Excavations in nerve-head: (1) physiological, (2) atrophic, and (3) glaucomatous excavations.

The *physiological cup* or *excavation* is usually present, and similar on the two sides, and, however deep and sharp-cut, always leaves a marginal ring of the disk undepressed. The vessels can generally be seen to emerge through



Randall

FIG. 132.—Curvilinear reflex-streak to the nasal side of distorted disk. The eye-ground appearances are given in (1) with the shimmering yet fairly fixed reflection concentric with the upper nasal nerve-margin of a stretching myopic eye. In (2) (copied from a section of such an eye) (Weiss: *Nagel's Mith.*) is shown the supra-traction of the choroid and the distortion of the nerve-head, projecting high on the nasal side, and furnishing as it passes into the retinal level the concave surface which gives back the reflection.

this tissue, which seldom overhangs the cup at all sides; and while the veins often present pulsation, this is rarely seen in the arteries unless the ocular tension is increased or aortic regurgitation is present (Fig. 131). An examination of the diagrams will make clear the differences between physiological and pathological excavations (see also p. 382).

Often there is a curvilinear reflex a little outside of the nasal nerve-margin, due to the concavity where the prominent disk sinks into the adjacent retinal level (Fig. 132). Weiss, who called attention to this, regards it as prodromal of myopic stretching. In like manner a double-ridged crescentic area to the nasal side was proven by Jaeger to be due to supra-traction of the choroid; and Nagel and Weiss hold it to be a feature in many myopic changes. While none of these things are pathognomonic, they deserve to be seen and weighed.

The **macula** or center of most distinct vision near the posterior pole of the eye is the most important, but generally least conspicuous, region of the retina. The pupil is apt to be at its smallest when this is illuminated, the eye least steady, the corneal reflex most annoying, and the accommodation most variable. Under these conditions some of the older authorities used to be skeptical as to the visibility of the *macula lutea*. "Yellow spot" it is not normally in life, but only a region of deeper coloration, generally maroon in tint, with a little shifting reflex at its center (*foveal reflex*). This, which is an inverted image of the ophthalmoscopic mirror given back from the pit-

like *fovea* as a concave mirror, has the form of the illuminated area of the ophthalmoscope—annular if the sight-hole is exactly centered before the pupil, but generally crescentic or comet-shaped if excentric. A tinier central point from the center of the fovea is sometimes seen.

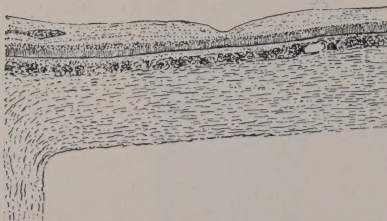
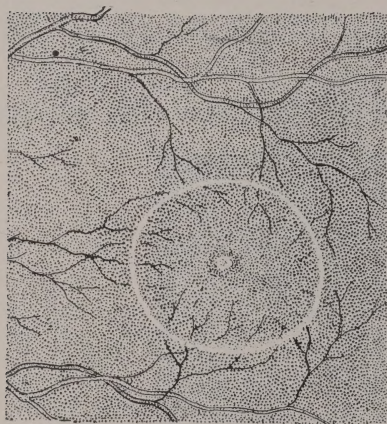


FIG. 133.—Halo around the macula as seen in its entirety and reflex from the fovea.

FIG. 134.—Minute vascularization of the macular region as shown by entoscopic study of the writer's right eye illuminated through a moving pin-hole.

Outside of the macula, where the change in retinal thickness begins, a *large ring* or *halo* (*macular reflex*) may be seen, complete only when the mirror is exactly central, generally partial and faint in the upright image. As in the

better definition of the indirect method, it constitutes a horizontally oval ring decidedly larger than the disk, and from 1 to 2 disk-diameters out from its lower border (Fig. 133). Like all retinal reflexes, these phenomena are best seen with a strongly concave mirror, and seem to shift somewhat above the retina, fading as we focus down to the exact level at which they arise—an additional proof that they are real images formed by concave reflecting surfaces. With advancing life all such reflexes are dim or lacking.

The center of the macula is devoid of blood-vessels, as may be best seen by the *entoptic* study (Fig. 134); and the ophthalmoscope, failing to reveal the capillaries which surround it, can best place it by the way in which vessels approach it from all sides without reaching it (with rare exceptions). Its most important blood-supply, like its nerve-fibers, comes from the temporal margin of the disk, and the occasional presence of an independent *cilio-retinal artery* has saved central vision in some cases of embolism of the central artery. More than in thicker parts of the retina, the stipple of the pigment-layer should be recognizable in all this region, and furnishes the most delicate focussing object in measuring the refraction in the optic axis. Senile changes are frequent in this region; albuminuric and other lesions are here most characteristic, and sometimes almost prodromal; and hemorrhagic lesions are not very rare; so its scrupulous study should be the rule (see pp. 416, 420).

The **periphery of the retina** offers no special peculiarities, and is difficult to see only in proportion to the narrowness of the pupil. It is the seat of the earliest changes in retinitis pigmentosa; its underlying choroid may show equatorial myopic stretching or splotches of disseminated choroiditis and other syphilitic affections—lesions that are often most marked up and in; while down and in, where skylight falls unobstructed by the brow, we commonly find any changes due to its irritation.

The **color of the eye-ground** is a composite blending of factors varying in value in every case. In blondes the sheen of the almost invisible retina is backed by the orange-red of the *chorio-capillaris*, veiled by little retinal pigment: back of this are the broader bands of choroidal vessels, through as well as between which light is reflected from the sclera. Only in the albino does this outer coat appear in its full whiteness, while in most eyes little light even reaches it through the pigmented tissues. The amount of pigmentation affects the tone and conceals the deeper layers in varying degree, until in the negro the retinal pigment gives a slaty *tapetum*, almost as reflecting as that in the lower animals. Every gradation of pigmentation can be seen, not only in different eyes, but almost in the same eye, since the periphery is generally less dark, and the choroidal structure may show everywhere except in the macula, where the pigment is richest. These peculiarities, especially at the nerve-margin, are worthy of note, verbal or graphic as well as mental, in a large proportion of cases, since they mark minor but often important changes there in progress. So too as to the *porus opticus*, which is rarely marked in the infantile disk, but soon becomes definite, and at times increases greatly through atrophy or mechanical pressure.

Physiological Variations and Congenital Anomalies.—Among the countless deviations from an ideal relation of the eye-ground picture, variation in the vessels is most common. Often the division of the vessels is within the nerve, and only the branches, perplexingly subdivided, appear on the disk. The distribution may be accomplished by most roundabout curves, the whole group of vessels passing inward, or in some other direction, before separating toward the different quadrants of the retina. The main blood-supply of the lower nasal retina may come from the upper nasal vessels (Fig. 130) or any similar irreg-

ularity ; and large areas, even in two quadrants, may be supplied by no branch of the central artery, but by a *cilio-retinal vessel* arising at the edge of the disk from the short ciliary vessels or communicating with the choroidal system (Fig.

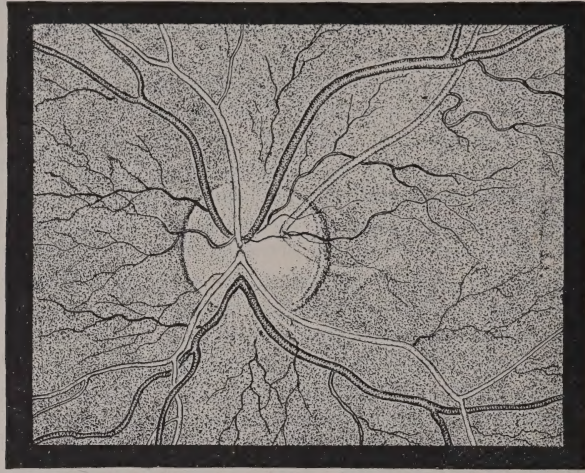


FIG. 135.—Choroido-retinal aberrant artery.

135). Tortuosity of vessels may be mere exaggeration of their normal sinuities ; but at times, especially in strained hyperopic eyes, they may have the marked curves, vertical as well as lateral, usual in neuro-retinitis. Single loops may lie across the disk or adjacent retina (Fig. 136) or protrude into the vitreous, or the single strand of the *persistent hyaloid artery*, generally devoid of blood, extends forward, in rare instances reaching or branching upon the posterior capsule of the lens. Small cystic outgrowths, especially to the nasal side, may mark a more atrophic stage of its condition (Figs. 137, 138).

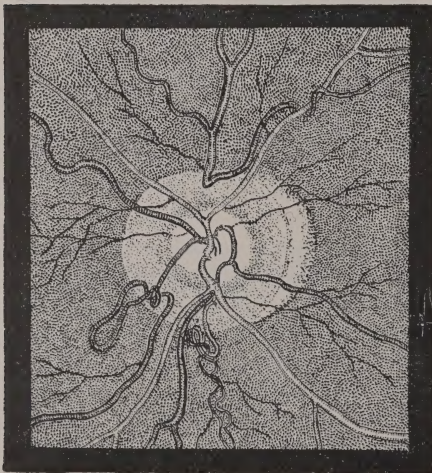


FIG. 136.—Looped and tortuous vessels.

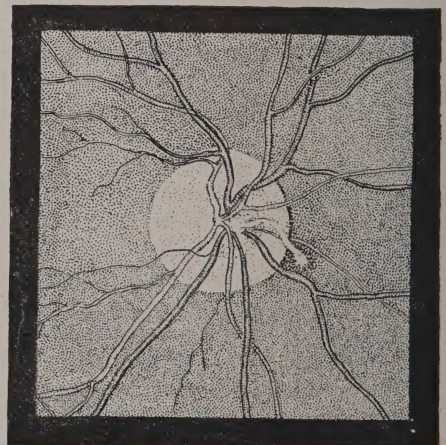


FIG. 137.—Persistent hyaloid artery.

Supernumerary depressions of the disk with emerging vessels are occasionally seen ; more often there is a *colobomatous gap*, due to incomplete closure

of the fetal cleft. This, which is normally open but for the sixth or seventh week, may be held open, probably by intra-uterine inflammation, and give rise to most various and extreme malformations. The disk may be alone colobomatous and show a depression, oftenest downward, of dark aspect and apparently

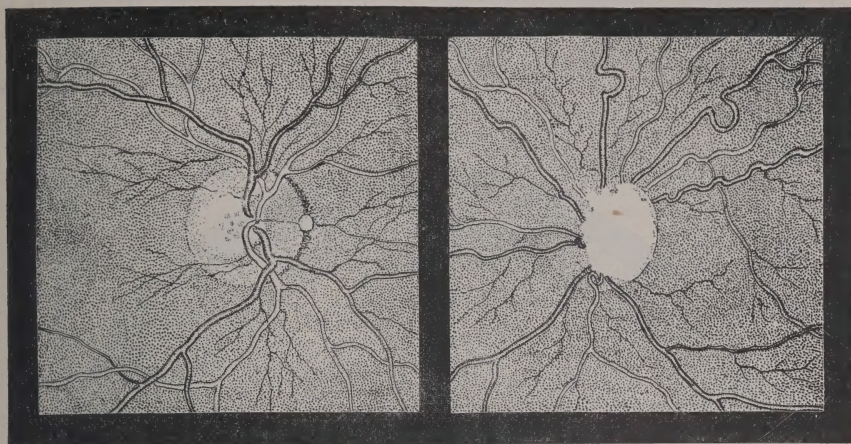


FIG. 138.—Cystic outgrowth on disk.

FIG. 139.—Fibrous outgrowth on disk.

immeasurable depth (Fig. 140), or the white sheath may be plainly seen beneath the gap. Sometimes the sheath alone is involved, and the disk, superficially normal, shows a peculiar greenish coloration near one margin that can be traced into its depths. Oftener the choroid shows a defect, usually downward, at times

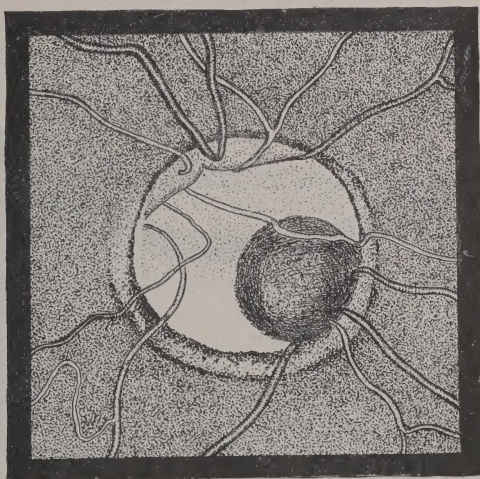


FIG. 140.—Coloboma of nerve and sheath.

involving nerve and sheath, and perhaps extending broadly as far forward as can be seen (Fig. 141), while coloboma of iris or lens, or both, marks the greater extension (in time as well as area). Difficult of explanation are those rarer cases in which the defect is outward, inward, or even upward, where the fetal cleft can hardly be supposed to have had influence. Gap of the retina alone, true persistence of the fetal cleft itself, has hardly ever been

described : some representative of retinal structure is usually present, when perhaps not even a vessel marks choroidal tissue, and the lack or stretching of scleral tissue forms a considerable staphylomatous concavity. Areas of defect at or near the macula (Fig. 142) are probably not related to the fetal cleft, but mark mere atrophy and non-development resulting from fetal inflammation—a process that may leave strands, knobs, or falciform folds of membrane protruding into the vitreous chamber, and is doubtless responsible for the persistence or perversion of most of that for which the faulty pre-natal development is held accountable.

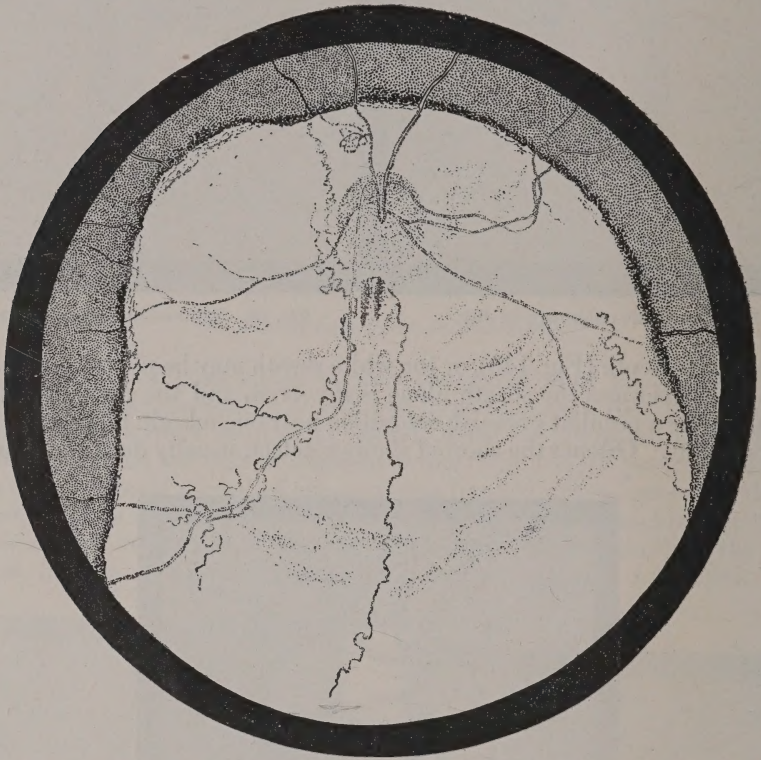


FIG. 141.—Huge coloboma of choroid, involving the nerve-head and extending to iris.

Conus was the name early given to the atrophic choroidal changes at the nerve-margin, which sometimes present a form suggestive of a cone. Oftener it is a crescent embracing the outer half of the disk—at times the nasal or other margin—in some cases annular, though generally broadest out. With this is generally associated an ectasia or *staphyloma posticum*, due to coincident atrophy or yielding of the sclera. Noted at first exclusively with myopia, many writers have denied the kinship of the crescents seen in other refractive conditions ; and there is little doubt that several groups of conditions ought to be differentiated, just as there are high myopias in the illiterate who do no close work, unrelated to the eye-strain myopia (Fig. 143). Any close and experienced observer has seen at times one of these forms (usually distinct) pass into another, generally with elongation of the visual axis ; and he recognizes the relation, although he may feel unable to define or explain it. Whether Hasner's theory of drag by the too short optic nerve

upon its scleral insertion has general or only occasional truth, the crescent most commonly begins at the outer margin as a region of altered color,

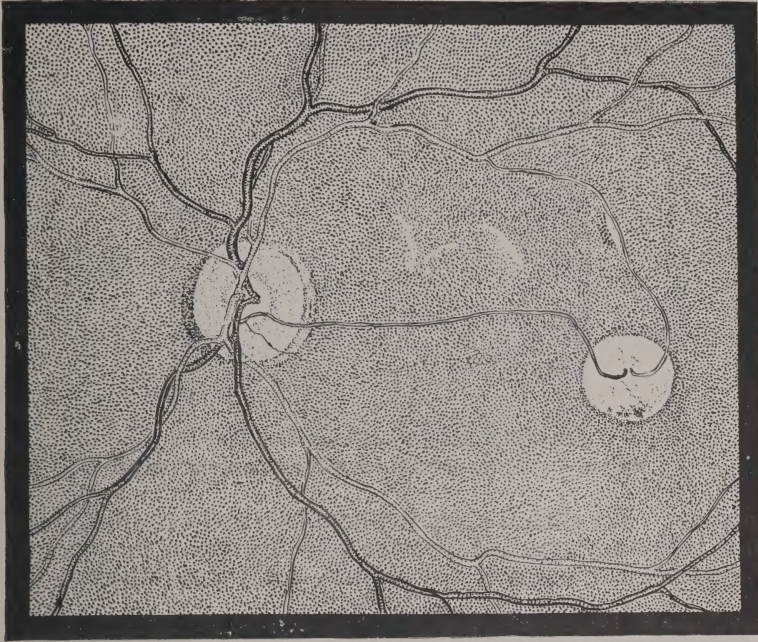


FIG. 142.—Coloboma of macula.

doubtless inflammatory. Pigment is absorbed, to be deposited in most cases at the outer margin of the crescent, and as the atrophy advances the area increases in size, usually by the demarkation of another crescent beyond.



FIG. 143.—Distorted myopic disk with scleral ring, atrophic and semiatrophic conus, aberrant artery, etc.

Three or four crescents at once may be thus shown in one eye in different stages of atrophic change. Rarely the process retrogrades and a crescent of altered color returns to the normal. Actual development of a large myopic

crescent may never have been fully observed, for in most cases it and the advance of the myopic stretching can be stopped by atropine and alterative tonics ; and some of us feel that our full duty has not been done in a case that

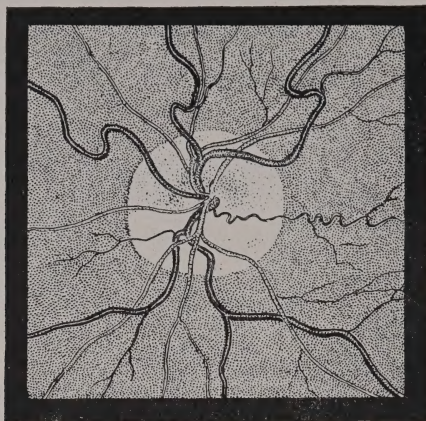


FIG. 144.—Underlying conus below, up to emergence of vessels.

does progress. Yet clinical study has been long and extended, and definite enough to bridge any gaps and show the usual identity of the processes ; and strong anatomical evidence to the contrary could alone disprove it.

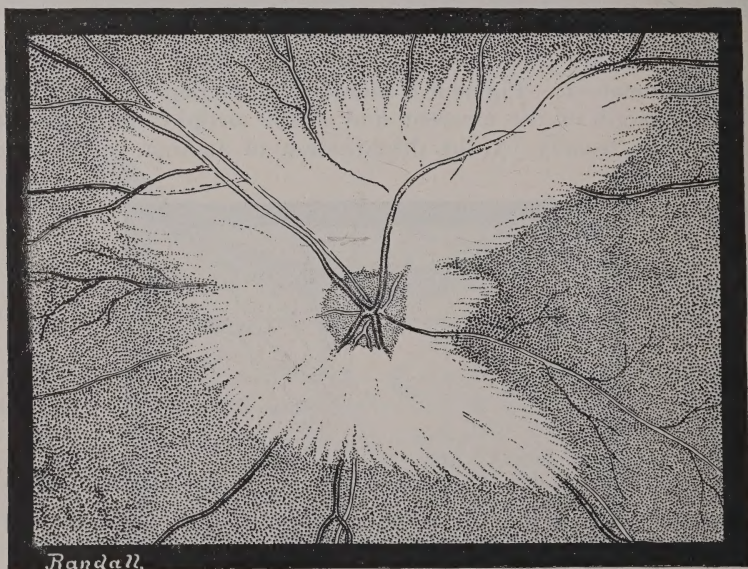


FIG. 145.—Retained marrow-sheath ; huge area surrounding disk.

Probably another matter is presented by the condition called "*congenital conus*," "*conus downward*," or "*underlying conus*." It has the form of a crescent of whitish color, apparently extending *in under* the margin of the nerve, generally below, although also noted in or out or at times even above. It is probably akin to coloboma of the nerve-sheath, although not merging

into this condition, seeming to underlie the upper layers of the nerve-head, and to extend in at times as far as the central vessels. Most like the "scleral ring," normally or morbidly revealed, it yet presents recognizable differences, which seems to mark dissimilarity of nature. Where it is marked, full acuteness of vision can rarely be attained; and the usual presence of notable astigmatism and the frequency of aberrant vessels passing through it point to it as a congenital defect (Fig. 144).

An interesting anomaly, sometimes most striking in appearance, is furnished by *marrow-sheaths on the retinal fibers*. Instead of being lost outside of the *lamina*, these elements are met in patches at or near the disk, of white fringed aspect, partly burying the retinal vessels under their opacity. The



FIG. 146.—Small isolated marrow-sheath patch up and out near macula.

rule in the rabbit and other animals, this is an exception in man, and may constitute a huge broadening of the blind spot (Fig. 145). If extensive, they are apt to extend outward in the line of the major upper and lower temporal vessels, forming a crescentic white patch, within which the macula is seen decentered out. At the nerve they are apt to overlies the margin and to cast a greenish shadow inward; which is, of course, more marked if there be any atrophy of the nerve. They may easily be mistaken for snowy patches of infiltration, such as the "snow-banks" of albuminuric or other retinitis, although generally far more fibrillar in their snowy whiteness; but the differentiation is not easy when they form small isolated patches unconnected with the disk (Fig. 146). Vision, except in the broadened blind spot, may be absolutely unaffected (see also p. 472).

METHODS OF DETERMINING THE REFRACTION OF THE EYE:

OPHTHALMOMETRY; OPHTHALMOSCOPY, SKIASCOPY, OPTOMETRY; THE USE OF MYDRIATICS.

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Ophthalmometry, more properly called **Keratometry**, is the measurement of the curvature of the cornea and the astigmatism due to the differences in that curvature in different directions. The ophthalmometer consists essentially of a telescope furnished, in connection with its object-lens, with some arrangement for doubling the images formed by it.

In the ophthalmometer of Helmholtz and that of Leroy and Dubois this doubling is effected by covering one-half of the object-lens by a piece of plate glass inclined in one direction, and the other half with a piece inclined in the opposite direction. The separation of the two images produced by this arrangement is the same at whatever distance the object is placed.

In the ophthalmometer of Javal and Schiötz the doubling is effected by a double prism, and the separation of the two images is only constant at a constant distance. To make sure that the images formed by the instrument shall always have this constant distance cross-hairs are placed within the barrel of the telescope. In using the instrument these cross-hairs must be in focus when the images are focussed; that is, the images must be formed at the plane of the cross-hairs. To effect this the eye-piece is so adjusted as to accurately focus the cross-hairs for the observer's eye, and then the images are focussed by moving the telescope to or from the eye under examination until they become distinct with the cross-hairs.

The *curvature of the cornea* is measured by determining how large an object is required to give a reflection from the cornea just equal to the separation of the doubled images. Knowing the size of the object, the size of its reflected image, and the distance of the object from the eye, the radius of curvature of the cornea is ascertained by a simple calculation. With the ophthalmometer of Javal—to which alone, as of most practical value, we shall refer—the distance of the object is always practically the same. It is determined by the distance from which the image of the corneal reflection will be formed at the cross-hairs.

The *size of the corneal reflection* is also constant, being the extent to which the doubling prism separates the two images at the constant distance. This being the case, the size of the object and the curvature (or radius of curvature) of the cornea are inversely proportioned to one another, so that a scale can be calculated upon which a certain size of object will correspond to a

certain radius of curvature of the cornea. Such a scale has been calculated and laid off upon the arm of the ophthalmometer. Along with it is placed a scale of diopters of refracting power, corresponding in an average eye to the different lengths of the radius of corneal curvature.

The instrument is shown in Fig. 147. The most striking part of it is the great metal disk which shades the surgeon from the light, and has on its margin figures to indicate the direction in which the arm is turned. Through the center of this disk projects the telescope, and just below it the arm, placed horizontally, is shown, with the two mires upon it, the fixed mire to the right, the movable mire to the left. On the right of the picture is the head-rest, with adjustable chin-support, and four electric lamps attached to illuminate the mires when good daylight from a space of open sky is not available. The telescope is mounted in a collar which allows it to be freely revolved on its

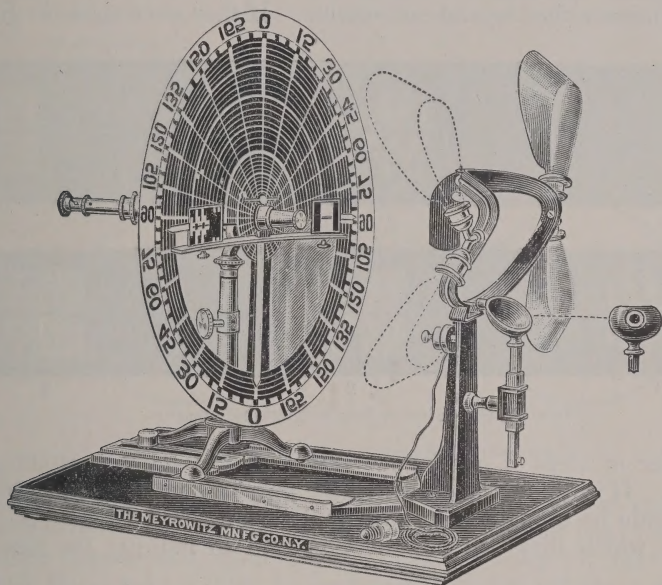


FIG. 147.—Javal-Schiötz ophthalmometer.

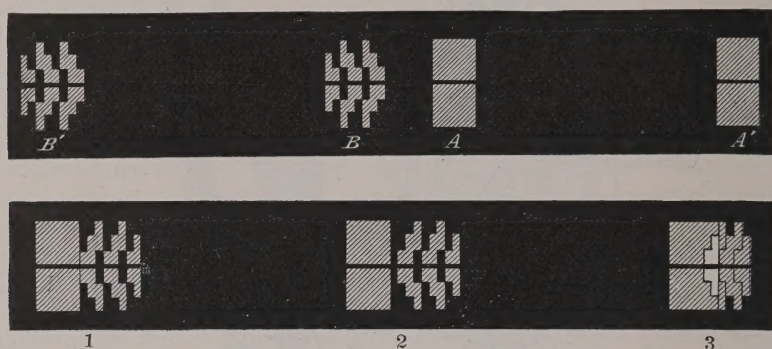
axis, carrying with it the graduated arm and mires, allowing the curvature to be measured in any meridian of the cornea. Unimportant variations as to the disk (which is in some models omitted), form of arm, method of illuminating, etc. are suggested by different writers, but the essential features of the instrument are those above indicated.

Method of Using the Ophthalmometer.—To use the ophthalmometer the instrument should be placed where strong light will fall upon the mires. The patient's face, which should be in comparative shadow, is placed in the head-rest, one eye covered with a metal shade and the other directed into the barrel of the telescope. The surgeon, glancing along the telescope, sees that it is turned toward the patient's eye. Then by the large screw passing through one foot of the tripod he adjusts the height of the telescope, and by moving the whole tripod back and forth focusses the corneal images within the instrument. What he sees is the doubled reflection of the disk and mires, one image of each mire (A and B, Fig. 148) being close together. The movable mire is then shifted back or forth along the arm until the edge

of its central image just touches the edge of the central image of the other mire (1, Fig. 149).

It will be noticed that each mire is crossed by a black line parallel to the arm. If the cornea is astigmatic, these lines on the adjoining images of the two mires appear continuous only when the arm is turned in the direction of one of the principal meridians of astigmatism. In other positions they seem relatively displaced. The telescope is now rotated on its axis until the direction of the arm is found in which the lines on the two mires correspond. The mires are then brought so that their images are quite accurately in contact, and the index on the movable mire indicates upon the scale on the arm the radius of curvature of the cornea, and corresponding refraction in one of the principal meridians.

The telescope is next rotated until the arm stands at right angles to its former position. If astigmatism be present, it will be found that in this position the mires either separate or overlap. If they overlap, as in Fig. 149,



FIGS. 148, 149.—Mires or targets of ophthalmometer.

3, the number of steps of overlapping indicates the number of diopters of astigmatism. If in this second position the mires separate, as in 2, Fig. 149, they must again be brought in contact and then rotated back to the former direction, in which they will now overlap and so indicate the amount of astigmatism.

If during the examination the patient looks away from the telescope, so that some portion of the cornea other than the center is presented, the refraction of this other part of the cornea will be indicated, differing, perhaps greatly, from that of the central portion of the cornea. Commonly, the first position in which the mires are brought in contact will be with the arm horizontal. But if it is found that in this position the black lines upon them do not correspond, do not come opposite one another, the instrument must be rotated either way until these become continuous one with the other. The position of the patient during the examination should be made as comfortable as possible by having the height of the instrument or of the patient's chair freely adjustable, and the examination must be completed quickly before the patient has become tired or restless. Ophthalmometry is of special value in cases of aphakia. In other cases the corneal astigmatism which it gives suggests approximately the meridians and amount of the total astigmatism.

Objective Methods for the Measurement of Refraction.—Rays of light to be focussed on the retina must enter the eye with a certain degree of divergence or convergence for each degree of ametropia. Rays coming

from any point of the retina and passing out of the eye travel the same paths in the opposite direction, and leave the eye correspondingly convergent or divergent. The refraction of the eye may be determined by ascertaining what divergence or convergence must be given to rays in order that they shall be focussed on the retina. Methods that do this are *subjective* methods for measuring refraction. Or we may take the rays from the retina and ascertain the degree of convergence or divergence which they have on emerging from the eye. Methods of doing this are *objective* methods for the determination of refraction.

The Ophthalmoscope.—1. **The Direct Method.**—The retina of the patient being illuminated by the ophthalmoscope, rays proceeding from it enter the eye of the surgeon and are focussed on his retina. If the surgeon is emmetropic parallel rays will be focussed on his retina, and the lens necessary to focus there the rays coming from the patient's retina is the lens necessary to make those rays parallel—*i. e.* the lens which corrects the patient's ametropia.

To determine which lens does this the surgeon watches the finest visible details of the fundus of the patient's eye. When the focussing is imperfect, these details are blurred; when perfect, they are seen clearly. Suppose a case of hyperopia, illustrated in Fig. 150, in which *P* represents the eye of the

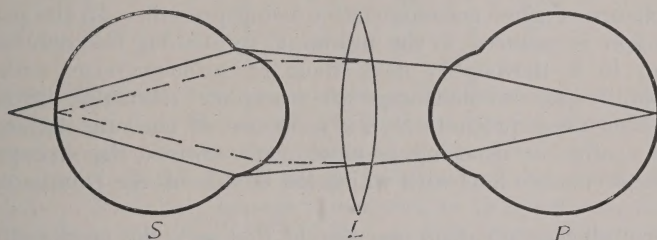


FIG. 150.—Eye of patient and surgeon measuring H.

patient, and *S* the eye of the surgeon. The rays from the patient's retina leave his eye divergent, and are directed to focus back of the surgeon's retina. By trial the convex lens, *L*, is found, which, rendering the rays parallel (see the dotted lines), causes them to be focussed on the surgeon's retina. This lens, *L*, which renders parallel the rays coming out of the patient's eye, is the correcting lens, the lens which would make parallel rays from some distant object convergent enough to focus them upon the patient's retina.

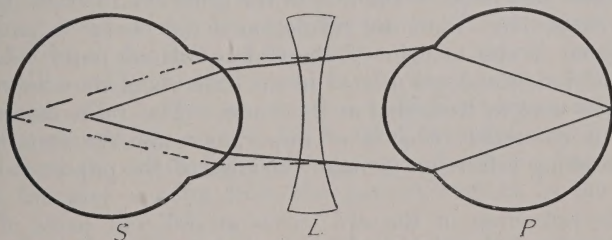


FIG. 151.—Rays in myopia.

In myopia (illustrated in Fig. 151) the rays emerge from the patient's eye convergent. A concave lens, *L*, is required to render them parallel, so that they can be focussed on the surgeon's retina; and this concave lens is the cor-

recting lens which, placed in the same position, would render the parallel rays coming from some distant object sufficiently divergent to be focussed on the patient's retina.

If the patient's eye is emmetropic, the rays emerge from it parallel, and require no lens to secure their perfect focussing upon the surgeon's retina.

What has been said of other forms of ametropia holds for regular astigmatism; only the ametropia differs in different meridians, and its correction in any one meridian affects the distinctness of lines in the fundus running at right angles to that meridian. Thus in an eye where the hyperopia in the horizontal meridian requires a 1 D. convex lens for its correction, and the hyperopia in the vertical meridian requires a 2 D. convex lens for its correction, the 1 D. convex lens renders clear the vessels which run horizontally, and a 2 D. convex lens is required to render clear the vertical vessels; the difference between the two lenses, 1 D., is the amount of astigmatism present.

In the practical use of the ophthalmoscope to measure refraction the chief difficulty is due to the influence of accommodation in the eye of either the patient or the surgeon. In any case the effect of accommodation is the same as the effect of a convex lens, partly correcting hyperopia and diminishing its apparent amount; or adding to myopia, and to that extent increasing its apparent amount. Accommodation in the surgeon's eye is guarded against by practice. Yet always in young eyes, particularly when tired or irritated, there is a chance of some accommodation being present. In the patient's eye accommodation is reduced to the minimum by making the ophthalmoscopic examination in a thoroughly dark room of sufficient size, with the gaze fixed on blank space to encourage the complete relaxation of the ciliary muscle. Using these precautions, the influence of accommodation is still to be guarded against by choosing, as most nearly correct, the strongest convex or the weakest concave lens with which the details of the fundus are clearly visible.

In determining astigmatism one should first seek the strongest convex or weakest concave lens with which the vessels running in any one direction are still clearly seen. This lens will give the hyperopia or myopia present in the meridian at right angles to those vessels. These vessels run in one of the principal meridians of astigmatism, the other being at right angles to this. Having determined the direction of the meridians and the lens required by one of them, the next point is to find what lens renders clear the vessels running at right angles to those seen clearly with the first lens. The difference between the two lenses gives the degree of astigmatism.

Another source of error in measuring refraction with the ophthalmoscope lies in the differences in the refraction of the same eye through different parts of the dioptric media. Thus the refraction at the centre is never the same as the refraction at the margin of the widely-dilated pupil. In some eyes without a mydriatic the pupil dilated in the dark room shows a very different refraction at its margin from that at its center. The refraction at the center of the pupil is commonly what is of importance, and the error which might occur by measuring refraction through the edge of the pupil must be guarded against.

Again, the refraction of the eye varies at different parts of the retina. In a perfectly spherical eye the refraction at the macula is least hyperopic or most myopic. The refraction of the anterior parts of the retina and choroid may be highly hyperopic, even in eyes quite myopic at the macula. Then, too, the depth of the fundus may vary in other ways, as from posterior staphyloma or cupping or swelling of the optic nerve entrance.

It is therefore important to select for the measurement of refraction the details of a certain part of the fundus, generally as near the macula as possible. For astigmatism the examiner should take as test lines the vessels running from the disk to the macula, with their lateral branches. The large vessels as they pass upward and downward from the optic disk are particularly liable to protrude into the vitreous, and thus give an appearance of astigmatism when none is really present. The pigment-layer of the retina and the vessels are usually the parts the refraction of which is measured; but the attention may be fixed upon any other detail seen within the eye. In glaucoma the refraction of the bottom of the cup may be compared with the refraction at the margin of the cup, or in optic neuritis the summit of the swelling may have its refraction compared with that of the retina beyond the swelling. By its refraction the surgeon may seek to locate an opacity in the vitreous. The distances in front of the plane of emmetropia indicated by a certain hyperopia, and the distances behind that plane indicated by an equal myopia, are shown in the following table, calculated for the average eye, having an antero-posterior axis of 22.824 mm. (see also page 178).

Diopters.	H. Diminution.	M. Increase.	Diopters.	H. Diminution.	M. Increase.
1	0.31	0.32	7	2.03	2.52
2	0.62	0.66	8	2.28	2.93
3	0.92	1.01	9	2.53	3.35
4	1.21	1.37	10	2.78	3.80
5	1.50	1.74	15	3.91	6.28
6	1.76	2.13	20	4.90	9.31

2. Indirect Method.—In using the ophthalmoscope by the indirect method rays coming from the retina are focussed by the object lens to form a real inverted image between that lens and the surgeon's eye. When they emerge from the eye parallel, this image is formed at the principal focus of the object lens. When they emerge divergent, as in hyperopia, the image is formed farther from the lens. When they emerge convergent, as in myopia, it is formed close to the lens. By ascertaining the exact distance of the image from the object lens one may determine the refraction of the eye. This has been attempted by placing a screen where the inverted image is most distinct, and measuring its distance from the object lens, but this method is not of practical value.

A modification of this, the *Schmidt-Rimpler method*, instead of the screen has a source of light of peculiar form, enabling the surgeon to judge when it is accurately focussed. To use it the object lens is placed exactly its focal distance from the principal plane of the eye, and by trial the surgeon finds what distance the ophthalmoscopic mirror must be held from the lens to give the most distinct view of the image of the source of light upon the fundus. This is obtained when the focus of the mirror coincides with the focus of the object lens; and a scale attached to the lens gives for each position of this image the amount of hyperopia or myopia to which it corresponds. Fig. 152 represents the course of the rays in this method, the solid lines indicating the rays reflected from the ophthalmoscopic mirror and entering the eye, and the broken lines, the rays coming from the patient's retina to the eye of the surgeon.

By the indirect method the nearer to the eye the object lens is held the smaller is the inverted image in myopia, and the larger it is in hyperopia. The change of size due to the change of distance of the lens in front of the patient's eye varies with the degree of ametropia. Hence the presence and kind of ametropia of high degree can be recognized by varying the dis-

tance of the lens from the eye. In hyperopia the withdrawal of the lens from the eye makes the image smaller, in myopia it makes it larger. In

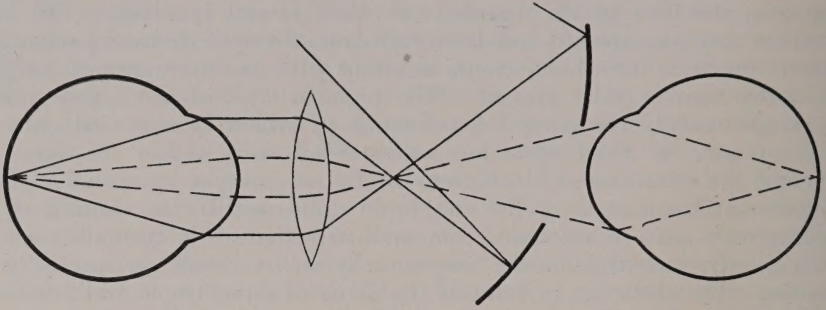


FIG. 152.—Course of rays in Schmidt-Rimpler's method.

astigmatism such withdrawal makes the disk relatively larger in the direction of the meridian of greatest refraction, and relatively smaller in the meridian of least refraction. This change in the form of the disk is an evidence of astigmatism, most noticeable in high mixed astigmatism.

Skiascopy; Retinoscopy; The Shadow-test.—The method of determining refraction with the ophthalmoscope by the position of the inverted image is of little practical value, because of the difficulty of ascertaining the exact position of that image and its nearness to the eye. Skiascopy is essentially a method of determining the distance of the inverted image from the patient's eye with great accuracy. Fig. 153 represents an eye in front of which

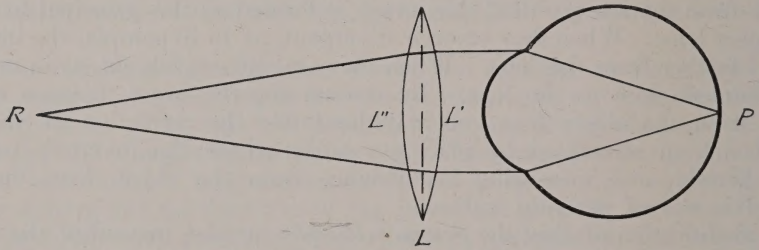


FIG. 153.—Eye with convex lens placed before it.

is placed a convex lens, causing the rays from a point, P , of the retina to be focussed at R ; the lens, L , may be regarded as composed of two lenses, L' and L'' — L' strong enough to render parallel the rays emerging from the eye, and L'' able to take parallel rays and focus them at R . By subtracting the strength of L'' from that of L , it is easy to get L' , the correcting lens. Suppose L to have a strength of 5 D., and R to be 1 m. (the focal distance of a 1 D. lens) from L . L'' will be 1 D., and $5 - 1 = 4$ D., the strength of L' required to correct the hyperopia.

The strength of L' to be deducted from that of L is found by determining the distance of R from the lens. In Fig. 154, representing the patient's eye (myopic) focussing the rays from A at C and from B at D , it will be noticed that if the surgeon's eye be placed at N , nearer the patient's eye than CD , the ray reaching it from A comes through the upper part of the pupil, so that A will appear at a in that direction. But if the surgeon's eye be placed at N' , beyond CD , the point A will appear to be located in the lower part of

the pupil toward a' , the ray from A reaching the surgeon's eye from that direction. In the same way, from N , B will appear in the lower part of the pupil, and from N' , in the upper part of the pupil.

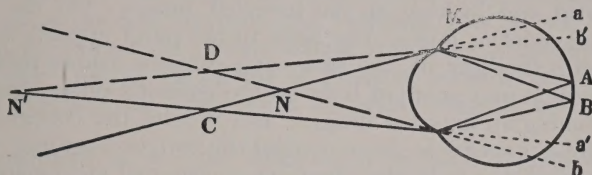


FIG. 154.—Showing how the rays cross, and so change their relative positions at the plane of reversal, D C.

This reversal in the apparent position of any given points of the retina occurs at the distance of C and D . Closer to the eye the point really above appears above; the retina is seen in an erect image. Farther from the eye, the point really above appears below, and the point really below appears above; the retina is seen in the inverted image. The change from the erect to the inverted image occurs at the point for which the patient's eye is focussed, either by its own myopic refraction or a lens placed before it; which point is, therefore, called the *point of reversal*.

The position of the point of reversal is determined with practical accuracy by observing the apparent direction of movement of light and shade in the pupil. The light is thrown on the eye with a mirror, usually a special form of the ophthalmoscope mirror, which may be either plane or concave. If plane, it should have a small sight-hole, 2 or $2\frac{1}{2}$ mm. in diameter, with its margin free from reflections. By turning the mirror slightly in different directions the light reflected from it on the patient's face, and also the portion entering his eye and falling on the retina, are made to move correspondingly. The movement of light and shade as it appears in the pupil is now watched. When the apparent movement is in the same direction as the real movement of the light on the retina, the erect image is being watched, and the surgeon's eye must be inside of the point of reversal, as at N (Fig. 154). When the apparent movement in the pupil is the opposite of the real movement of light on the retina, an inverted image is being watched and the surgeon's eye is beyond the point of reversal, as at N' . By studying these opposite movements on the two sides of the point of reversal that point is located.

With a certain movement of the mirror there is always the same movement of the light on the face whether the mirror be plane or concave. Thus, when the mirror is made to face upward the light moves upward across the patient's face. If the mirror is turned down, the light moves down across the patient's face. With the *plane mirror* the light on the retina always moves in the same direction as the light on the face—in the same direction, or *with* the mirror. With the *concave mirror* the light on the retina always moves in the direction opposite to that of the light on the face—always moves *against* the mirror (Fig. 155). The reason for this is that with the plane mirror the light enters the eye as though coming from an image (called the *immediate source* of light) as far behind the mirror as the real or *original source* is in front; but with the concave mirror the *immediate source*—the point from which the light seems to come to the eye—is a small inverted image of the *original source* of light, formed in front of the mirror.

Hence, with the plane mirror, if the light in the pupil appears to move *with* the mirror—with the light on the face—the surgeon knows that the point

of reversal is not between him and the patient. But when, with the same mirror, the apparent movement of light in the pupil is *against* the mirror—in the opposite direction to the movement of light on the face—he knows that the point of reversal is between him and the patient—that he is beyond the point of reversal and looking at the inverted image. On the other hand, when with the concave mirror the light in the pupil appears to move *with* the mirror—with the light on the face—the surgeon knows that this is the opposite of the real movement of light on the patient's retina, and that, therefore, he is watching an inverted image. But if with the concave mirror the light in the pupil appears to move *against* the mirror—against the light on the face—knowing this to be the direction of the real movement of light on

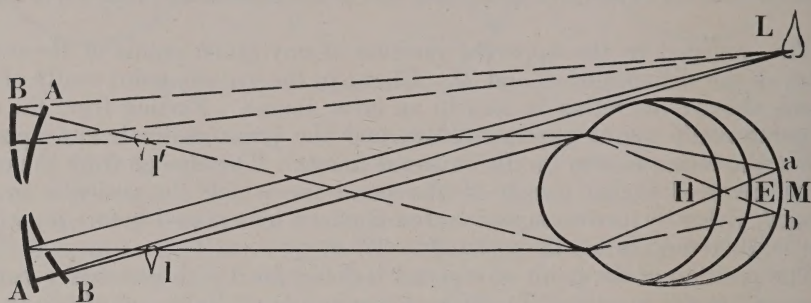


FIG. 155.—Course of rays in skiascopy with concave mirror: *A A*, one position of mirror giving immediate source of light at *l*, and illuminating retina toward *a*; *B B*, another position of mirror with immediate source of light at *l'*, and retina illuminated toward *b*.

the retina, he knows he is watching an erect image, the point of reversal being somewhere behind him.

Rate of Movement, Form, and Brightness of the Light-area.—Besides the direction of the movement of light and shadow, the brightness and form and rate of movement of the illuminated area in the pupil are of practical importance. At the point of reversal a single point of the retina appears to occupy the whole area of the pupil. As the point of reversal is departed from, more and more of the retina is seen in the pupil. Hence, near to the point of reversal a slight movement of the light-area on the retina will appear to carry the light entirely across the pupil—the light and shadow move in the pupil swiftly. But at a greater distance from the point of reversal they move slower.

The apparent form of the light-area in the pupil is also modified by the nearness of the surgeon to the point of reversal. The actual form of the light-area on the retina is commonly circular. This circle appears greatly magnified when the surgeon is near the point of reversal, and only a small part of its margin can be seen in the pupil at one time, the boundary between light and shade appearing almost a straight line. While far away from the point of reversal, especially if the surgeon be near the pupil, the whole area of retinal illumination may be seen in the pupil as a complete circle. More important still in determining the apparent form of the light-area are regular astigmatism, aberration, and irregular astigmatism, to be presently considered.

The brightness of the light-area in the pupil depends on the concentration of the light thrown into the eye and the extent to which the retina is magnified. The immediate source of light being commonly near the mirror, the light is most concentrated on the retina when the mirror is held near the point of reversal. But just at the point of reversal the magnification of the

retina makes the illumination appear feeble, so that the brightest area of light in the pupil is obtained about 1 or 2 D. from the point of reversal.

Practical Application of Skiascopy.—The room should be thoroughly darkened, and the source of light shaded with an opaque chimney having a circular opening opposite the brightest part of the flame.

For the plane mirror the source of light should be so arranged that it can be brought quite close to the mirror and moved with the mirror to or from the patient's eye, and the opening in the shade should be 5 or 10 mm. in diameter.

For the concave mirror the flame is to be back of the patient's head, generally as far from the mirror as possible; and if a shade is used, the opening should be 10 to 20 mm. in diameter.

When not otherwise stated, the following description refers to skiascopy with the plane mirror. It may be applied to the concave mirror by reversing the significance of the direction of movement of the light in the pupil:

1. *Hyperopia*.—Without a lens the light moves across the pupil with the light on the face. The convex lens, L (Fig. 153), strong enough to overcome the hyperopia and to give a point of reversal, R , is placed before the eye. The surgeon, then varying his distance from the patient's eye, tries the movement of light and shadow alternately from within R , where the movement is *with*, and from beyond R , where the movement is *against*, the light on the face. The position of the point of reversal is thus determined. Its distance from the patient's eye is then measured or estimated. This is the focal distance of the over-correcting effect of the lens L , which over-correcting effect, subtracted from the whole strength of the lens, leaves the strength required to correct the hyperopia.

Suppose a 5 D. convex lens placed before the eye gives movement with the light on the face at 20 in. (51 cm.), and against the light on the face at 30 in. (76 cm.), the point of reversal taken as midway is at about the focal distance of a 1.5 diopter lens; the over-correcting effect of the 5 D. lens equals $5 - 1.5 = 3.5$ D.—the strength of the lens required to correct the hyperopia.

In making the final determination of the refraction, if the freedom of the eye from astigmatism and aberration allows the movement of light and shadow to be easily watched at a greater distance, a weaker lens, giving a point of reversal farther from the eye, may be used. But if there be much irregular astigmatism or aberration, the determination can be more correctly made with a point of reversal still closer to the eye.

2. *Myopia*.—From the myopic eye the rays emerge already convergent to meet in a point of reversal that can be determined without the use of any lens, except in myopia of very low degree. Commonly, however, it is too close to the eye for accuracy, and a concave lens partly correcting the myopia should be placed before the eye, and the remaining myopia measured and added to the strength of the concave lens for the total myopia.

For example, in a case of myopia of 10 D., a concave 9 D. lens being placed before the eye, the point of reversal is found at 1 m. This corresponds to myopia of 1 D., which, added to 9 D., the strength of the lens, gives 10 D., the total myopia. In the case of very low myopia, as only 0.25 D., a convex 1 D. lens is placed before the eye, and the point of reversal found in this case at 31 in. (78.5 cm.), indicating 1.25 D. of myopia. From this, by subtracting 1 D., the strength of the lens, we get 0.25 D., the myopia originally present.

3. *Emmetropia* is shown when the convex lens placed before the eye gives a point of reversal just at its focal distance.

4. *Regular Astigmatism*.—In regular astigmatism the rays coming from the retina emerge from the cornea with different degrees of divergence or convergence in different meridians. For the two principal meridians there are, therefore, always the two separate points of reversal, their distance apart indicating the amount of astigmatism.

When in such an eye a point of reversal is found, it is soon discovered that it is a point of reversal only for the movement in one direction. The

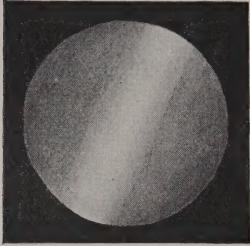


FIG. 156.—Band-like appearance in shadow test.

surgeon's eye, placed at this point, sees the retina magnified enormously in the direction of the one meridian, and magnified much less in the other principal meridian. This makes the light-area in the pupil appear elongated in the direction of the first meridian, giving it a *band-like appearance*, shown in Fig. 156.

To make this band-like appearance most distinct, the immediate source of light should be at the point of reversal for the other meridian. With the plane mirror the surgeon must place his eye at the point of reversal nearest the eye, where he will get movement undistinguishable in one meridian, and *with* the light on the face in the other. The original source of light is then to be pushed away from the mirror, its reflection (the immediate source) retreating correspondingly behind the mirror until it reaches the point of reversal for the other principal meridian. The direction of the band-like appearance is to be carefully noted as the direction of the principal meridian of greatest refraction—the direction for the axis of a convex cylinder that would correct the astigmatism. The direction of the other principal meridian, the direction for the axis of a concave cylinder to correct the astigmatism, will be at right angles to this.

With the concave mirror the surgeon's eye should be placed at the point of reversal that is the farthest from the eye and the original source of light brought closely to the mirror, causing its conjugate image (the immediate source of light) to go farther from the mirror and closer to the patient's eye, until it reaches the nearer point of reversal, and the band-like appearance appears most distinct in the meridian of least refraction. In this position the band cannot be seen to move in the direction of its length, but at right angles it also moves *with* the light on the face.

Having determined the direction of the principal meridians of astigmatism, the hyperopia or myopia in each is to be measured separately, just as hyperopia or myopia would be measured in any other case, with the light as near the plane mirror as possible or as far away as convenient from the concave mirror. The difference of refraction between the two meridians is the amount of astigmatism. When it has been determined, a cylindrical lens correcting it should be placed with the proper spherical lens before the eye, and the test applied to ascertain if the correction is really complete.

Aberration.—In most eyes the refraction at the edge of the dilated pupil is more myopic or less hyperopic than at the center. In this form, called *positive aberration*, the point of reversal for the edge of the pupil is nearer the eye than the point of reversal for the center, and from the latter point movement of light *against* the light on the face is to be noticed in the edge of the pupil. This light in the edge is brighter than the light at the center of the pupil, and great care must be taken to avoid error on this account. When the center of the pupil is the more myopic it is called *negative aberration*. The circular distribution of aberration largely determines the shape of

light and shadow in the pupil, making it more circular when otherwise it would be of different shape, as in regular astigmatism.

When aberration is present the point of reversal for the margin of the pupil may be close to the surgeon's eye, while the point of reversal for the center is far from it. In this case the movement of the light in the center of the pupil will be slow, while in the margin it will be swift. The light-area then appears to swing around a fixed center, and assumes an angular shape, shown in Fig. 157. This is the appearance presented in conical cornea where the center of the pupil is more myopic than the margin.

Irregular Astigmatism.—The differences of refraction due to the lens-changes preceding cataract, or the irregularities of the cornea following phlyctenular keratitis, break up the light and shadow in the pupil into small irregular areas. The surgeon must find which of these areas is most likely to be of use for eye-work, and measure the refraction in it. To do this it may be necessary, on account of the smallness of the area, to come quite close to the patient's eye. Here a small source of light and a small sight-hole in the mirror are of great importance.

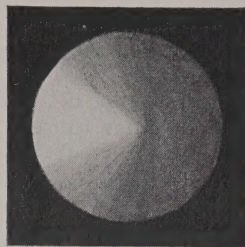


Fig. 157.—Angular appearance in high aberration.

Subjective Methods of Testing Refraction.—To determine what lens is required to bring perfectly to a focus the rays entering the eye we may resort to tests based upon a single point of light. Thomson's *ametrometer* consists of two small gas-flames, one fixed and the other movable along a graduated arm, which can be revolved about the first as a center. The distance of the two flames apart when their diffusion-areas appear to just touch each other gives the degree of ametropia in the meridian parallel to the graduated arm. Hotz uses two small holes in a disk placed in front of a window or lamp-flame. To the patient having astigmatism each of the points of light so obtained appears elongated, and by turning the disk so that these elongated images lie in the same line, an index enables the surgeon to read off the direction of the principal meridians of astigmatism.

The simple *optometer* consists essentially of a convex lens which is placed close to the eye, and a graduated arm extending from it on which moves a card bearing test-type. In emmetropia the type can be seen distinctly only as far as the focal distance of the lens. In hyperopia it is read to a greater distance, and in myopia only to a lesser distance, corresponding to the degree of the ametropia.

Either of the above subjective methods may be found of service where others are not available; but they are not commonly used, and by the subjective method of determining refraction is commonly meant the method with trial-lenses and test-letters.

The *trial case* contains a sufficient series of spherical and cylindrical lenses, with trial-frames in which they can be placed before the eye, prisms, solid, pin-hole, and slit disks, and colored glasses. By combining two or more lenses together a very few convex and concave lenses can be made to answer for any case of ametropia, but where many cases are to be tested convenience and economy of time demand a fairly complete set of lenses. This may include pairs of convex and concave lenses, with 0.12 D. intervals to 1.5 D., 0.25 D. intervals to 4 D., and 0.50 D. intervals to 8 D., for both sphericals and cylindricals. Then for the sphericals, 1 D. intervals to 20 D., with, perhaps, 25 D. and 30 D. added. The prisms may run by 1-centrad intervals to 10, with the 12, 15, 20, and 30 centrad prisms in addition.

To use the trial-lenses, test-letters suited to the distance adopted are to be hung in a strong light, either natural or artificial, the latter being preferable because it can be made more uniform. The test-card should always have one or two lines of letters smaller than those intended to be read at the distance adopted. Thus for 6 m. there should be a line of 5-m. letters. Some patients have visual acuteness greater than $\frac{6}{6}$.

Use of the Trial Case.—The *pin-hole disk* furnishes a ready means of distinguishing between imperfect vision due to ametropia and imperfect vision due to other causes. In the former case the placing the pin-hole opening before the eye lessens the diffusion-areas upon the retina and improves vision; if the imperfection of vision is not due to ametropia, the pin-hole disk rather makes it worse.

The *slit* is used in discovering astigmatism of moderate or high degree and the direction of its principal meridians. In astigmatism the diffusion-areas on the retina are wider in the direction of one principal meridian than in the direction of the other. The slit limits them at right angles to its length, but not in the direction of its length. When, therefore, it is placed before the eye, turned in one direction, it cuts down the diffusion-area in its larger dimension, giving the greatest improvement of vision. At right angles to this it limits the diffusion-area in the other direction, in which it is already most limited, and gives the least improvement of vision. These directions of the principal meridians of the astigmatism being found, the slit may be turned in the direction of one meridian and spherical lenses tried until one is found correcting the ametropia in this meridian, and giving the best vision obtainable through the slit. The same is done for the other meridian, and in this way the correcting lenses, both spherical and cylindrical, may be determined. This test has practical value as an approximate and confirmatory test.

In the *ordinary use of test-lenses* each eye is tested separately, the other being covered by a solid disk or ground glass. When accommodation is absent the aim is to find the lenses which give the best vision. Some idea of the ametropia is given by previous objective tests and the acuteness of vision without a lens. The concave or convex lens expected to correct it approximately is placed before the eye and the vision with it noted. Then weak additional convex or concave lenses are held in the hand in front of this, trying first the one, then the other. If the first lens has been convex, and the additional convex spherical further improves vision, a convex lens correspondingly stronger is substituted. The trial is then repeated, and this is continued until a lens is found which can neither be increased nor diminished in strength without lessening the acuteness of vision.

If the eye is free from astigmatism, this is the lens desired; but to test such freedom from astigmatism cylindrical lenses should be tried. The cylindrical lens is to be held in front of the spherical lens selected, and its axis turned in different directions, as vertical, horizontal, and oblique to the right and to the left. For this purpose the astigmatic lens, convex in one meridian and equally concave in the meridian perpendicular thereto, is preferable to either the convex or concave cylinder. Such astigmatic lenses should be included in the trial case.

Having ascertained that in some one direction the cylindrical lens improves vision, such a lens is to be placed in the trial-frame, either with the spherical lens already there or with one slightly weaker if the cylindrical lens is of the same kind, or a slightly stronger if the cylinder is of the opposite kind. Thus, if the original spherical lens was + 2 D., and + 1 D. is the

cylinder to be combined with it, the spherical should be changed to + 1.5 D. If it is preferred to use a — 1 D. cylinder, the spherical lens should be changed to + 2.5 D. After this the cylinder is to be slightly turned, first to one side and then to the other, the patient being required to indicate when the turning makes his vision worse. This is repeated until it is pretty certain just what direction of the cylinder-axis gives the best vision. Then weak convex and concave spherical lenses are to be tried in front of the combined spherical and cylindrical lenses, to see if either will still further improve the vision, and these are followed with the astigmatic lens and a new trial of the direction for the axis. This routine is to be repeated until any change in any factor of the combination impairs the acuteness of vision.

The combination thus arrived at is the correcting lens of the eye for the distance at which the test is made. If this distance be 4 or 6 m., 0.25 or 0.17 D. must be subtracted from the convex or added to the concave spherical lens to make it the perfect correction for truly parallel rays from more distant objects. The same process is repeated for the second eye.

When the power of accommodation is present, the aim must be to find the strongest convex or the weakest concave spherical lens that gives the best vision. Cylindrical lenses will be tried as above, preferably before attempting the final determination with the spherical lens. The determination of the spherical lens is best effected by testing both eyes at once and beginning with convex lenses that are too strong or concave lenses that are too weak to permit of the best vision. Then, if convex, before removing such glasses the next weaker lenses should be placed before the eyes. In this way whatever relaxation of accommodation has been secured under the first lenses is preserved. If vision is yet not perfect, a still weaker lens is substituted in the same way, and so on until the best vision of which both eyes are capable is obtained.

The eyes are then to be tested separately by covering each of them alternately. If it is found that only one eye has attained to its best vision, the lens before the other eye is to be still further weakened until it, too, has obtained its best vision. The lenses thus chosen will be found to correct the total hyperopia in the majority of even young persons.

In myopia the spherical lenses are to be made successively stronger, and when the best vision is obtained the eyes are to be tested separately by alternate covering.

MYDRIATICS.

The drugs atropin, duboisin, hyoseyamin, hyoscin, daturin, and scopolamin, alkaloids obtained from members of the Solanaceæ, and homatropin, a derivative of atropin, constitute the true mydriatics. Applied to the eye, they produce dilatation of the pupil and paralysis of the accommodation, which after a time, varying with the drug and the amount of it employed, entirely passes away. In some cases the dilatation of the pupil is of use in the determination of refraction, since it renders easier the use of the ophthalmoscope, skiascopy, and the test-lenses. But the chief value of these drugs in this connection lies in their action as cycloplegics. By paralyzing the ciliary muscle they eliminate the influence of accommodation.

In healthy eyes a single drop of one of the following solutions is usually sufficient to accomplish this: atropin, 1 : 100, duboisin, hyoseyamin, or scopolamin, 1 : 250. Of homatropin hydrobromate a single drop of even a saturated solution will not paralyze the accommodation. It must be used by repeated instillations of a 2 to 4 per cent. solution at short intervals. Any of the other drugs will prove effective in weaker solutions if the instillations

are repeated. In practice it is customary to prescribe either atropin, duboisin, or hyoseyamin in solutions of the strength named, to be instilled at the patient's home three times a day for one or more days. The repeated instillations are necessary to guard against their possibly imperfect character.

Homatropin should be instilled by the surgeon or a trained assistant, and the instillations repeated every five or ten minutes until from four to six have been made; and after its use the determination of the refraction should be completed within one or two hours, as it often begins to lose its control of the ciliary muscle soon after that time.

In the choice of the mydriatic homatropin has the advantage of greater brevity of action. The accommodation completely recovers from its effect, usually within forty-eight hours, while after atropin two or three weeks are required before it is quite recovered, and after the use of the other drugs named from one to two weeks must elapse. Scopolamin, 1 : 500, is an efficient mydriatic, used by making two instillations one hour apart. Accommodation will completely return in six days. Even weaker solutions may be efficacious.

In using these drugs certain alarming intoxicating effects must be borne in mind. While in the amount mentioned most people do not experience these, in exceptional cases a single drop of one of the solutions mentioned, except of homatropin, may cause severe symptoms of intoxication. These are—dryness and redness of the throat and skin, with delirium and incoordination of movement, especially inability to walk. The patient is not usually much disturbed, but his friends may be greatly alarmed, although from any such dose these symptoms are quite unattended by danger. On their appearance the use of the drug must be suspended, the patient kept quiet, given water freely, and, if decidedly delirious, small doses of an opiate.

Homatropin is much the least likely to produce such symptoms, and duboisin, hyoseyamin, and scopolamin (which may be but different names for the same drug) are the most likely to produce them. In the eyes of a few persons these mydriatics produce marked conjunctival irritation or inflammation, and the homatropin solutions mentioned always produce a temporary hyperemia of the conjunctival and pericorneal vessels during the period of absorption.

Cocain, a drug of an entirely different class, possessing little or no power to paralyze the ciliary muscle, may be useful to dilate the pupil in persons over fifty years of age whose pupils are small and whose power of accommodation is not sufficient to interfere with tests for refraction. A single instillation of a 2 per cent. solution is followed after thirty minutes or an hour by decided enlargement of the pupil, yet with very little inconvenience and no danger.

All drugs which cause dilatation of the pupil, except cocain, are dangerous in eyes presenting the essential changes of glaucoma, since they may produce a glaucomatous outbreak. But if such a revelation of the presence of glaucoma is promptly met by the proper treatment, it can hardly be regarded as unfortunate for the patient. No eye in which this accident can occur is likely long to escape glaucoma, and without the mydriatic the advent of this disease might be so insidious as to escape detection until irreparable damage had been done.

Whether mydriatics should be used in the great mass of refraction cases is a debated question. That with their use the determination of refraction can be more certainly exact cannot be doubted. The question is as to

whether the increased certainty and accuracy are worth the discomfort and loss of time from ordinary occupations that the mydriatic causes. In deciding this question the desires of the patient and the appreciation of exactness in his work on the part of the surgeon will be the determining factors.

Table of the Different Mydriatics.

Name of drug and salt commonly used.	Relative power in solutions containing the same amount.	Strength of solution commonly used.	Time in which such solutions produce a noticeable effect.	Beginning of maximum effect.	Effect begins to decline.	Recovery complete.
Atropin sulphate.	30	1:120	12 min.	1 hour.	4 days.	15 days.
Daturin sulphate	60	1:200	10 "	40 min.	3 "	10 "
Hyoscyamin sulphate . . .	75	1:240	10 "	40 "	2 "	8 "
Duboisin sulphate	75	1:240	10 "	40 "	2 "	8 "
Scopolamin hydrochlorate.	75	1:1000	15 "	1 hour.	12 hours.	6 "
Homatropin hydrobromate.	1	1:40	15 "	1 "	3 "	2 "
Cocain hydrochlorate . . .	{ Not com- parable. }	1:125	30 "	1 "	2 "	12 hours.

With cocain the anesthetic effect passes off before dilatation of the pupil is fairly commenced. The new local anesthetic, eucain, is usually regarded as having no mydriatic effect, but Wagenmann states that, by a strong solution repeatedly applied, some dilatation of the pupil may be produced.

Euphthalmin in 5 to 10 per cent. solution produces dilatation of the pupil, which begins in ten minutes after its instillation, and reaches its maximum in about an hour. Its influence on accommodation is relatively slight, so that it has no practical value as a cycloplegic. It is the best agent we have to produce brief dilatation of the pupil under a strong light. Combined with cocain, it produces satisfactory mydriasis for the examination of the eye, with the least annoyance to the patient and the most rapid recovery.

GENERAL PLAN OF EXAMINATION.

The acuteness of vision for each eye separately, and the near point of distinct vision, should be first ascertained. If vision be imperfect, the pin-hole disk may be tried to see if such imperfection is due to ametropia or to other causes. Then the eye should be examined with the ophthalmoscope by the direct method. This gives a rough approximation of the refraction, especially as regards hyperopia or myopia. After this skiascopy may be used or a mydriatic employed. Then the corneal astigmatism may be measured with the ophthalmometer.

When the mydriatic has produced its full effect, the refraction is to be carefully measured by skiascopy, and then to be tested by the trial-lenses, commencing with the glass fixed upon by the shadow-test. The value of the results obtained by the subjective method depends largely on the patient not being wearied by prolonged testing.

After the correcting lenses have been thus ascertained, the eye should be allowed to recover from the mydriatic and the trial with lenses repeated. Such a routine, carefully followed by one of fair skill, cannot fail to give accurate and reliable results.

NORMAL AND ABNORMAL REFRACTION :

EMMETROPIA, AMETROPIA, HYPEROPIA, MYOPIA, ASTIGMATISM, PRESBYOPIA.

BY EDWARD JACKSON, A. M., M. D.,

OF PHILADELPHIA.

DISTINCT vision, by which the existence and position of different objects are recognized, as contrasted with mere perception of light, depends on the assorting or focussing of the light that falls on the retina. Imperfect focussing of this light causes imperfect vision. To avoid this the accommodation may be strongly exerted, contraction of the pupil secured by a bright light, or the space between the lids narrowed. But efforts of this kind to improve vision, if frequently or constantly resorted to, are liable to exhaust the endurance of the nervous system or disturb the nutrition of the eyeball and its appendages.

Errors of refraction lead either to imperfect vision or to eye-strain. They may lead to both, but generally, in so far as the vision is imperfect, there has not been eye-strain, and in so far as there has been eye-strain the imperfection of vision has been partly overcome. If the defect be great, the part of it overcome may cause eye-strain, while beyond this some remains to render the vision still imperfect.

Normal and Abnormal Refraction: Emmetropia and Ametropia.—Refraction may be regarded as normal when it gives, under the requirements to which the eyes are subjected, distinct vision without injurious effort. It is, for practical purposes, abnormal when distinct vision is prevented by imperfect focussing of light on the retina or is obtained only by excessive effort—by eye-strain.

In *emmetropia* light from distant objects (parallel rays) is accurately focussed on the retina without accommodative effort. Any departure from this optical condition of the eye constitutes *ametropia*. Emmetropia is the ideal state of refraction. In it not only are rays from distant objects perfectly focussed without effort, but rays from near objects are focussed upon the retina with the minimum exertion of accommodation; not only are distant objects seen distinctly, but the full extent of the accommodation is available for the distinct seeing of near objects. It is true that the myopic eye may be able to see objects still nearer to the eye, but the gain of a very few inches or a fraction of an inch of distinct near vision is more than balanced by the loss of distinct vision for everything beyond a certain very limited distance; and the gain in lessened accommodation required for near objects is more than balanced by loss through the increased need for convergence. Careful examination of large numbers of eyes, particularly among school-children, shows that the actual experience of life fully supports the theoretical advantage of emmetropia.

The same observations show that exact emmetropia is comparatively rare.

The writer among 4000 eyes found the following proportions of ametropia of different kinds, and of emmetropia :

Frequency of Ametropia.

Compound hyperopic astigmatism	1610 eyes, or	40.2 per cent.
Hyperopia	1225 "	30.6 "
Compound myopic astigmatism	361 "	9. "
Mixed astigmatism	267 "	6.7 "
Simple hyperopic astigmatism	249 "	6.2 "
Myopia	158 "	5. "
Simple myopic astigmatism	79 "	2. "
Emmetropia	51 "	1.3 "

It may be asked, If emmetropia is the ideal state of refraction, why is it so rarely found? The answer is that the shape of the eye results from processes of growth resisting intraocular pressure, and cannot be a rigid, definite, mathematical form. The ideal form for any part of the body, and the ideal of proportion between different parts, are never found in life. The deviations of the eye are insignificant compared with the deviations of the other organs, but sufficient to cause errors of refraction of practical importance in a very large proportion of eyes. The study above referred to indicates that the largest number of eyes have low hyperopia; 62 per cent. show hyperopia of 1.5 D. or less, including hyperopic astigmatism. The eye has been evolved to meet the requirements of life among the lower animals and savages, for whom myopia, even of low degree, would be a very dangerous defect. Deviation of the eye in that direction caused the extinction of individuals and families. The requirements of modern civilized life, however, rapidly extend in the direction of near eye-work, so that hyperopia becomes a serious defect. Even the emmetropic eye may be unable to meet the requirements of close work; and as the power of accommodation diminishes with age, it loses the power of distinct vision at short distances, requiring optical assistance in all cases (*presbyopia*).

Eye-strain.—The *symptoms* arising from excessive efforts to prevent indistinctness of vision may be considered under this head. They are largely the same in different forms of ametropia, and may also arise from excessive eye-work, insufficient light, or other unfavorable conditions, even though the eyes be emmetropic. Eye-strain is caused by excessive use of the accommodation, from too long hours of close work, or by looking at small objects brought too near the eye; or because of deficient vision, or in making good the defect of hyperopic eyes; or by ordinary near work after the accommodation has diminished with age (*presbyopia*). It may also arise from excessive efforts to keep the eyes properly directed, as of convergence where objects have to be brought too close on account of uncorrected myopia, or from the effort of accurately co-ordinating muscular movements, as those of accommodation and convergence. It may come by exhaustion of the visual centers in the effort to appreciate blurred and imperfect retinal images, or it may be due to the use of eyes otherwise normal at a time when the general nutrition is impaired by wasting disease or exhaustion by effort in other directions.

Eye-strain may be manifested by failure of near vision after use of the eyes (*relaxed accommodation*) or by temporary blurring of distant vision (*spasm of accommodation*); by changes in the retina—swelling and opacity, with dilatation of the retinal vessels and exaggerated reflexes; by changes in the optic nerve—redness, haziness, or opacity or swelling of the nerve-head; by changes in the choroid, including increased redness, or alteration of color by edema or atrophy; and, secondary to the changes in the choroid, by opaci-

ties in the vitreous and the crystalline lens, and softening of the sclera with local bulging (*posterior staphyloma*).

The progressive changes in refraction, to be discussed under Myopia, are also symptoms of eye-strain. Acute or chronic conjunctivitis may arise from the same cause. This may amount to a slight exaggeration of the irritation felt when the eyes are tired, or it may develop into a chronic catarrhal conjunctivitis, practically incurable even by removal of the original cause. When the conjunctivitis is severe, corneal disease may be associated with it, and if chronic it is apt to be attended with changes in the lids, marginal blepharitis, stytes, etc. Eczema of the lids and neighboring parts has also been ascribed to eye-strain and relieved by wearing glasses.

The symptoms manifested outside of the eye and its appendages are—

Headache.—This is often spoken of as reflex, but is better regarded as due to nerve-exhaustion. It is commonly frontal, in some cases extending to the occiput or throughout the whole head. Sometimes it is strictly limited to one side—*hemicrania*. It may be directly associated with the use of the eyes, or be apparently constant, or may occur at certain times, apparently not determined by any particular eye-work, and yet in the latter case may be as completely cured by the careful relief of eye-strain as when more evidently connected with eye-work. The headache of eye-strain is not *sui generis*. It has the same characters as headache arising from entirely different causes. In many instances it is partly due to eye-strain and partly to the other causes. If the other causes can be discovered and removed, it may be cured without the wearing of glasses or any reduction in eye-work. More frequently it is cured by the correction of ametropia or faulty habits of using the eyes. Sometimes, when removal of one factor has given temporary relief, but the headache returns, the discovery and removal of the other factor may be necessary to make the relief permanent.

Neuralgic pains in other portions of the body or attacks of migraine may arise from eye-strain. Anorexia, nausea, vomiting, palpitation of the heart, and similar disturbances may be due to eye-strain. Nervousness, which the patient speaks of as an intolerable desire to cry out or do some violent act, inability to keep quiet after prolonged eye-work, peevishness and irritability of temper, are among its manifestations. For the rarer forms of disturbance the therapeutic test by relief from the strain will be necessary to establish the diagnosis. Eye-strain may cause certain motor disturbances, as twitching of the lids, tonic blepharospasm, and in rare cases choreiform movements or epileptiform seizures, or it may be the most substantial cause of hysterical manifestations. With these, as with headache, eye-strain is usually but one of two or more factors.

Hyperopia.—*Hyperopia, Hypermetropia, or Far-sightedness, is the error*

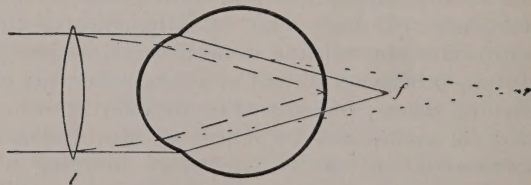


FIG. 158.—The course of rays in a hyperopic eye.

of refraction which arises when the retina is situated in front of the principal focus of the dioptric surfaces.

Fig. 158 represents a hyperopic eye able to focus parallel rays at f behind

the retina and l the lens which, turning the rays toward r , the virtual "far point" of the eye, causes them to be focussed on the retina and corrects the hyperopia.

The hyperopic eye is adjusted for convergent rays, and these are not encountered in nature. Without accommodation it sees indistinctly at all distances. By the exertion of accommodation it sees clearly, but only by the exertion of accommodation exceeding (by the amount of its hyperopia) that required of the emmetropic eye; and, having to use some accommodation constantly, it is deprived of the periods of rest which come to the emmetropic eye when fixed on distant objects. The greater amount of accommodation required of it causes the hyperopic eye to suffer earlier from the diminution of accommodation by age, and afterward the further loss of accommodation deprives it of distinct distant vision. We have from hyperopia liability to eye-strain and indistinctness of vision, either of which may become an indication for correction of the defect by convex lenses.

Causes, Varieties, and Course.—Hyperopia is due in the majority of cases to antero-posterior shortening of the eyeball, *axial hyperopia*. This is caused not so often by a flattening of the globe as by a diminution in all its diameters. The other causes for it are—flattening of the curvature of the cornea or crystalline lens, *hyperopia of curvature*, and removal of the crystalline lens (accidental or operative), or its congenital absence or dislocation—*aphakial hyperopia*. It is possible to conceive also of hyperopia due to a low index of refraction of the crystalline lens—*index-hyperopia*.

At birth nearly all eyes are hyperopic. It is possible that during the first years of life there is some general tendency for hyperopia to diminish, although this is not proven (see p. 178). On the other hand, from early adult life to old age there is a general tendency for hyperopia to slowly increase, due to the gradual increase in size of the crystalline lens. As Priestley Smith has shown, the lens, like other structures of epithelial origin, continues to increase so long as it continues healthy, increasing one-third in bulk between twenty-five and sixty-five years of age. Increase in the size of the lens, supposing it to keep the same shape, causes an equal increase in its focal distance and a corresponding increase of hyperopia. This is independent of the apparent increase due to the failure of accommodation, and continues after all power of accommodation has been lost.

The varieties of hyperopia recognized in practical work are based on the relations of hyperopia to the accommodation. They can be best illustrated by an example: Suppose a case of hyperopia of 10 D. in which the total accommodation is only 8 D. When the full power of accommodation is exerted, there remains 2 D. of uncorrected hyperopia. This, a part of the hyperopia which no effort of the accommodation can correct, is called the *absolute hyperopia*. It often happens where there is considerable hyperopia and good accommodation that the accommodation is not fully relaxed at any time when the eyes are used, even for distant vision. If this part of the accommodation amounts to 2 D., then so much hyperopia is always corrected when the eyes are in use; it is called *latent hyperopia*. Besides the 2 D. of accommodation that cannot be relaxed, there remains 6 D. of accommodation which can be relaxed or exerted, and which, therefore, can be used to correct an equal amount of hyperopia, but which hyperopia can be left uncorrected at will. This part of the hyperopia which can be corrected or not by the accommodation is called *facultative hyperopia*. The absolute hyperopia and the facultative, added together, give the *manifest hyperopia*. The manifest hyperopia, with the latent hyperopia, together constitute the *total hyperopia*.

The relations of these different varieties or parts of the hyperopia may be better understood by the following diagram :

Total accommodation.		
Involuntary A.	Voluntary A.	
Latent H.	Facultative H.	Absolute H.
Total hyperopia.		Manifest H.

The subject may be still further illustrated by considering what happens when successive convex lenses are placed before an eye with a hyperopia of 10 D., and a total accommodation of 8 D. Without any lens the vision of such an eye is imperfect. A weak convex lens improves it, and the improvement continues as the strength of the lens is increased up to 2 D., which corrects the absolute hyperopia, and, with all the power of accommodation added to it, focusses parallel rays on the retina, giving good distant vision. As the convex lens is made stronger the vision is not further improved, but the best vision is obtained with less exertion of accommodation. Thus, with a 4 D. lens it is necessary to exert only 6 D. of accommodation, and with a 7 D. lens only 3 D. of accommodation. This continues until all the manifest hyperopia is corrected by an 8 D. lens, the vision remaining clear with only 2 D. of accommodation. If, however, a still stronger lens is placed before the eye, the accommodation being able to relax no farther, the 2 D. of accommodation, plus the lens, gives an over-correction, blurring distant vision. The portion of the accommodation which cannot be relaxed has been indicated in the above diagram as *involuntary*, and the part that can be relaxed or exerted at will is *voluntary* accommodation. By the use of a mydriatic the total accommodation, both voluntary and involuntary, is relaxed and the total hyperopia revealed.

Absolute hyperopia only occurs after the power of accommodation for objects at a distance from the eye has fallen below the amount of hyperopia. In early life it is only seen in hyperopia of the highest degree. After middle age, the power of accommodation being lost, it appears in all hyperopic eyes, and when the accommodation is entirely gone all hyperopia is absolute. Latent hyperopia may not be present. Many persons with strong accommodation are able to relax it entirely when looking at distant objects through convex lenses. In other eyes it is constantly present, and in still others is present only part of the time. The inability to relax the accommodation is often spoken of as *spasm of accommodation*. Such spasm is most likely to occur when the eyes are irritated or fatigued. The facultative hyperopia, lying between the latent and the absolute, varies with these, decreasing as either of them increases, and on the whole tending to diminish with age along with the diminishing accommodation. In measuring refraction without a mydriatic the important point is to get as much of the hyperopia manifest as possible, and to do this the two eyes must be tested together, as recommended on page 209.

With reference to these different varieties it is essential always to bear in mind that their relations to each other are not fixed—that there is no constant ratio between the manifest and the latent hyperopia at any particular age or for the individual. The proportions may vary from day to day, or even from minute to minute.

Symptoms.—Since hyperopia may be corrected by accommodation, only the highest degrees give rise to symptoms in early childhood. The earliest symptom is *convergent squint*, arising with the effort of accommodation. This

effort being great, the nervous impulse overflows, causing additional muscular contractions in muscles closely associated with that of accommodation, and especially excessive contraction of the internal recti muscles. Convergent squint of this kind is apt to begin before six years of age, and is most commonly associated with hyperopia of high, but not the highest, degree. Squint occurs where the hyperopia can be corrected by great exertion of the accommodation. When this is too difficult imperfect vision is accepted. Such imperfect vision may be noticed by a careful observer in early childhood, but commonly is not detected until the child begins to read. It is then found that to increase the size of the imperfect retinal images the book is held very close to the eyes, as in myopia. This practice in early childhood quite as frequently indicates high hyperopia.

Under the influence of school-work lower grades of the defect begin to cause eye-strain. This often shows itself in local congestion and inflammation of the conjunctiva and lids, conjunctivitis, stytes, photophobia, and frequent winking on account of the conjunctival irritation. In later childhood begins the liability to headache; young children rarely complain of ocular headache. During school-life even the lower grades of hyperopia are liable to cause eye-strain, but afterward, most eyes being used to better advantage and not being so severely taxed, the low degrees of defect are less likely to cause trouble, although headaches established during childhood may be continued, and periods of poor health may cause the development of eye-strain.

As the time approaches when even emmetropic eyes suffer from presbyopia, hyperopic eyes manifest the same symptoms earlier, in proportion to the degree of hyperopia. These symptoms are—failure of the vision for near-work, particularly in the latter part of the day or when tired or working by poor light: print has to be held farther from the eyes in order to be read, and conjunctival irritation and inflammation again occur, often in repeated acute attacks that are ascribed to “cold.” Still later, as the power of accommodation falls so low that it can no longer correct the hyperopia, indistinctness of vision is developed.

Treatment.—While any departure of the refraction of the eye from the emmetropic standard constitutes an error or an anomaly of refraction, it is only when under the conditions of work imposed upon the eye such an error or anomaly causes interference with vision or strain, that the refraction is to be considered abnormal. Treatment, therefore, is not indicated by the mere existence of hyperopia, but by the fact that the hyperopia has caused symptoms, or is likely to cause them, under conditions of work to which the eyes are about to be subjected. Many hyperopic eyes, therefore, do not require the aid of correcting lenses, but when symptoms arise that may with probability be ascribed in part to this error of refraction the correcting lenses should be used.

How they are to be determined has been sufficiently indicated in the preceding section (page 198). The general rule should be to give the full correction—that is, the lens which makes the hyperopic eye similar to the emmetropic eye, enabling it to focus parallel rays on the retina without any exertion of accommodation, and to focus divergent rays with the least effort of accommodation. To this general rule certain objections are offered which must be carefully considered, and certain exceptions which must be recognized.

It is urged that if some eyes continue normal with uncorrected hyperopia, others may continue normal with their hyperopia but partly corrected, and that the rule should be to give the weakest glass that will allow the use of the eyes with comfort. But it is impossible, except by trial, to know that

any incomplete correction will be sufficient in the particular case. The full correction promises the greatest degree or the greatest probability of relief after the eye has once become accustomed to it. The inconvenience of wearing glasses is the same with a partial as with a full correction; therefore, if the patient must wear glasses at all, he ought to have from them the greatest benefit or the greatest certainty of benefit obtainable.

The second objection to giving the full correcting lens is that if a portion of the hyperopia is latent—and it is often incorrectly assumed that this is so in nearly all cases—the wearing of the full correction renders distant vision indistinct. If the latent part of the hyperopia were a fixed amount, this objection would have more practical weight. As it is, one cannot correct the manifest hyperopia of to-day and be sure that the same lens will not over-correct it to-morrow. As long as latent hyperopia is allowed it will vary, and, at certain times, lead to blurring of distant vision unless a very wide margin is left for such variation. On the other hand, it is only necessary to wear constantly the full correcting lenses to render the total hyperopia manifest. Sometimes this is accomplished in a few minutes or a few days; in other cases it may take weeks, but if the glasses are a true correction and are steadily worn, it can always be brought about. This manifestation of total hyperopia is doubted by some ophthalmologists, partly because of the failure of patients to wear their glasses constantly or always to look through them when worn, but chiefly on account of the inaccuracy of supposing that the correcting lens for a limited distance, 15 or 20 feet, is a true correction for greater distances. Such a lens causes a very perceptible blurring at greater distances, very annoying to persons accustomed to distinct vision, and never to be overcome by any amount of persistence in wearing glasses. The person who under a mydriatic sees perfectly at 4 m. with a 1 D. convex lens never will see perfectly at a longer distance with that lens—never will accept such a lens with satisfaction, not because of any “spasm of accommodation,” but because it is not his correcting lens for parallel rays; it is 0.25 D. too strong. (See also page 209.)

A third objection is that even if finally accepted the full correction is harder to become accustomed to than a partial correction. This seems plausible, but experience indicates that it is not the case unless the partial correction is so incomplete as to give a very diminished assistance to the eye. It appears to be easier for an eye to learn to relax its accommodation entirely than to learn the new partial relaxation that a partial correction of the hyperopia renders necessary. Some surgeons claim it is best to arrive at full correction by successively increasing partial corrections. The full correction may at first cause the greater trouble, but this is at its maximum during the first two or three days, and after that it rapidly diminishes; it is certainly less in the aggregate than is entailed by a series of increasingly stronger glasses, which, moreover, cause greater expense.

The wearing of correcting lenses should be constant. This should be the rule in hyperopia, although not so essential as in myopia and astigmatism. Some indications as to the constancy with which glasses should be worn may be drawn from the symptoms. Headache, particularly if continuous or occurring without apparent connection with any particular use of the eyes, is very much more likely to be relieved when the lenses are worn continuously. The same is true of chronic conjunctivitis and marginal blepharitis and of inflammatory changes within the eye. Where there is headache or irritation directly following special use of the eyes, as in reading or sewing, which quickly passes away when such eye-work is suspended, it is likely that

relief will be afforded by using the correcting lenses only during the periods of such work.

It is often necessary to have the glasses worn continually at first, until the headache or chronic inflammation has been entirely cured and the eyes have learned the habit of relaxing accommodative effort when not working. After this it may be quite enough to use the glasses only when the accommodation will be especially taxed. Again, many children have trouble from hyperopia, requiring the use of correcting lenses during school-life, who, when they leave school, can lay aside glasses and continue free from any symptoms of eye-strain.

Exceptions to the prescribing of a full correction are made—first, in young persons with good accommodation and high degrees of hyperopia and with comparatively trifling symptoms, occurring only when the eyes are especially taxed; second, in cases in which it is impossible to persuade the patient to submit to some present inconvenience in the hope of future benefit. Under these circumstances the only thing to do is to give a very incomplete correction at first and increase the strength of the lenses slightly at short intervals. Patients who take this attitude are generally in a position to bear the increased expense, and if it is explained that the first glasses are only for temporary use and are to be changed after short intervals, perhaps changed several times at such intervals, the partial correction may be resorted to. Deficiency of convergence or marked *exophoria* may also be considered as an indication for not completely correcting hyperopia.

In cases of convergent squint the constant wearing of the full correction is always to be tried. Apart from the wearing of correcting lenses, there is no treatment for hyperopia; but the symptoms that arise from it may be relieved by diminished use of the eyes, especially for near work, or by improvement of general health, and by the influences and remedies that bring it about.

Myopia.—*Myopia, Brachymetropia, Short-sight, or Near-sightedness, is the error of refraction existing when the retina is situated back of the principal focus of the dioptric surfaces, and rays of light to be focussed upon it must enter the eye divergent from some comparatively near point.*

Fig. 159 represents a myopic eye focussing parallel rays at *f* in the vitreous,

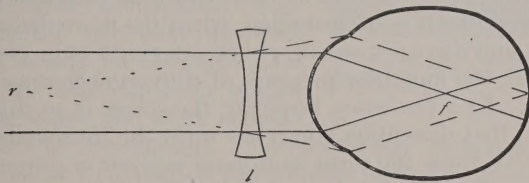


FIG. 159.—The course of rays in a myopic eye.

and requiring the lens *l*, which will cause them to diverge from *r*, the far point of the eye, in order that they shall be focussed on the retina.

Causes, Tendency, and Varieties.—Myopia may occur as the result of a simple congenital tendency to the formation of too long an eyeball or too great curvature of its dioptric surfaces, but the great mass of myopic eyes must be regarded as pathological. They exhibit distinct, and often very grave, lesions of the ocular tissues, to which the myopia may be secondary, but which it tends to aggravate.

The sclera is distended by a normal intraocular pressure of 25 or 30 mm. of mercury. This pressure preserves the form of the eyeball and the proper

relation of the dioptric surfaces to each other and to the retina. The normal sclera resists this pressure without yielding. Acute disease, diathetic impairment of general nutrition, a local inflammatory process starting with congestion of the choroid from eye-strain, or a congenital nutritive deficiency lowers the resisting power of the tissue, leaving it unable to withstand the intraocular pressure. Distention then occurs, commonly near the posterior pole of the eye, causing elongation of the antero-posterior axis of the eyeball.

When such distention is started, anything tending to increase intraocular tension or to diminish the resisting power of the sclera favors it. Different writers attach different degrees of importance to the various possible factors. Some believe a diathetic vice of nutrition essential to the production of myopia; some regard external pressure, dependent largely upon the form of the orbits and the width between them, as most important; some consider inflammatory changes within the eye as the chief cause of distention; some ascribe an important influence to accommodation, and others to excessive convergence. The writer recognizes the possible influence of all these factors, but believes excessive convergence is by far of the greatest practical importance.

It is universally recognized that prolonged near work favors the occurrence and increase of myopia. Such near work causes physiological hyperemia, often exaggerated by poor light or excessive minuteness of the objects looked at; faulty position of the head, leading to venous congestion of the eyes; confinement indoors to a sedentary occupation, which impairs nutrition; strain of accommodation; and excessive convergence which, sooner or later, increasing myopia renders necessary.

When the eye has become myopic its elongation makes convergence abnormally difficult, and the continued use of the eye for near work, because it cannot be used for distinct distant vision, increases the amount of convergence required of it. With weakened sclera, with increased pressure of the extraocular muscles from increased convergence-effort, and the pressure abnormally continuous, the tendency is for distention to increase. Myopia tends to be *progressive*. Probably all cases of myopia are at the start progressive. Some myopias cease to increase when the requirements of excessive near work made temporarily or during school-life are relaxed. Others become stationary from increasing rigidity and resisting power of the sclera which seem to come normally with increasing age. Still other cases continue progressive until convergence becomes too difficult to be sustained, when the more defective eye is permitted to deviate, and *divergent squint*, either intermittent or constant, is established. After this, the muscular pressure of convergence ceasing, the myopia ceases to increase. In a few cases, however, the sclera is so thinned, its resisting power so low, that distention continues until the intraocular changes produce blindness. To these the term *malignant myopia* is properly applied.

Myopia reaches much higher degrees than hyperopia, and the high myopias constitute a larger proportion of the cases; myopia of over 20 D. is as common as hyperopia of 10 D.

In speaking of degrees of myopia we may designate as *low myopia* that of less than 2.5 D., where some accommodation is habitually employed for near work. *Moderate myopia* is from 2.5 D. to 5 D., where near work can be done without accommodation. *High myopia* ranges from 5 to 10 D., in which work is best done at the far point of distinct vision. *Very high myopia* is above 10 D., and is usually accompanied by great alteration in the shape of the eyeball and changes in its coats.

Symptoms and Complications.—Myopia renders indistinct all objects situated beyond the far point of the eye. Such indistinctness is not always

noticed if it begins in early childhood or comes on very gradually, although generally it is detected by the patient or his care-takers, especially by inability to see letters on the blackboard at the ordinary distance. The indistinctness is removed by bringing the object closer to the eye, by placing before the eye a solid disk or card with a pinhole opening, or by looking through a concave lens. The changes within the eyeball often prevent full vision even with correcting lenses. The small moving specks or shadows due to points of haze or unequal refraction in the vitreous humor, noted in all eyes under certain optical conditions, are especially noticeable in myopic eyes. Such eyes are also especially liable to vitreous opacities, which give rise to more extensive clouds and shadows upon the retina.

Objectively, the myopic eyeball may appear noticeably enlarged and elongated, especially when turned strongly toward the nose; and the lids over it prominent or widely separated. The pupil is often rather large, and apparently sluggish, because less often contracted in the act of accommodation or convergence. The myope has a vacant or even stupid look, due to inability to see and respond to expression on the faces of others, and shows a distinct inclination toward reading and other pursuits which do not require clear distant vision.

The ophthalmoscope commonly reveals intraocular changes closely associated with the causation and increase of the myopia. The most characteristic of these are alterations in the choroid, as congestion and edema, causing reddening, blurring of details, and lighter patches ("woolly," "fluffy," or "patchy" choroid), and changes in which the pigment in parts of the fundus is reduced, while it may be increased in others ("disturbed" or "moth-eaten" choroid or choroidal atrophy, "slight," "partial," or "complete"). These changes are most frequent at the outer side of the optic disk, usually taking a crescentic form—the *myopic crescent* represented in Fig. 160. An eye may present two or three well-marked successive crescents, the one next the disk characterized by nearly or complete choroidal atrophy, the next showing partial atrophy, and the outer one mere congestion or disturbance of the choroid. The continued succession of such areas, extending outward and passing on to complete atrophy, gives rise to a triangular area of atrophy extending to the temporal side of the disk, the so-called *conus*. The disturbed area may extend around the disk, forming a ring of atrophy usually broadest to the temporal side (see also pp. 192, 193).

Such an area is often the seat of softening of the sclera, with consequent distention and thinning—*posterior staphyloma*. When this occurs at the temporal side of the disk the optic-nerve entrance is tilted, so that it is seen more obliquely. The disk appears a narrow oval. The vessels, drawn upon by the distention, pass more directly outward; the temporal side of the opening in the sclera through which the nerve enters is made prominent as a white crescent, also a "*myopic crescent*." The whole appearance is well characterized as a "*dragged disk*." If these changes occur at the lower, nasal, or upper side, the disk is found "*dragged*" in that direction. In the later

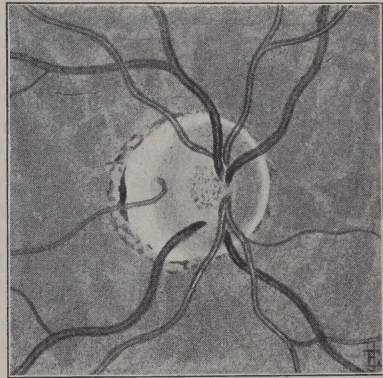


FIG. 160.—The myopic crescent. Figure illustrates also the lamina cribrosa and a cilio-retinal vessel.

stages of high myopia similar lesions of the choroid are to be found in other parts of the fundus, especially about the macula, where a small lesion may cause great impairment of vision. In the earliest stages, and later if under the influence of eye-strain the myopia is increasing, general hyperemia and disturbance of the choroid may be noticed. Late in the course of high myopia *vitreous opacities*, *cataract*, especially nuclear and posterior polar, and *detachment of the retina* are liable to occur.

Course.—The best statistics of eyes examined at birth show that practically none are then myopic. But high myopia is sometimes encountered in early childhood, and probably sometimes does exist from birth. In the great mass of cases it certainly develops later. In a very few it seems to occur through a healthy development of the eyeball, to go on without choroidal changes or other evidences of disease up to adult life, and then to become stationary. In the great mass of cases *axial myopia* begins in a period of marked ocular congestion accompanying near work; then at times it becomes stationary; at other times, those of especial strain, it rapidly increases. When the myopia is arrested during early life it continues for some years stationary; later, by the slow growth of the lens, referred to under Hyperopia, it may be lessened or finally disappear entirely. In a few cases myopia begins during adult life or old age in connection with degenerative changes in the choroid and sclera, and may be a symptom of *diabetes*. *Curvature myopia* may begin at any time of life after disease causing corneal distention, *conical cornea*, or after injury causing partial dislocation of the lens. *Index-myopia* comes in old age as a precursor of cataract, the so-called *second sight*.

Treatment.—The indistinctness of vision is remedied by concave lenses. Permanent avoidance of near work will usually check the progress of myopia, but it is generally necessary to check its progress while near work is continued, and fortunately this also is possible for the great mass of cases by the use of correcting lenses. Two factors in near work that might tend to increase myopia are accommodation and convergence; but accommodation is far more tasked in hyperopia, and hyperopic eyes show no such tendency as the myopic eyes to distention of the eyeball. On the other hand, hyperopia is an obstacle to straining convergence, while myopia favors or compels it. The tendency of myopia to increase does not disappear when by its progress accommodation is reduced to a minimum or becomes unnecessary; but it does often cease when, binocular vision being given up, convergence is no longer required. If excessive convergence causes myopia and keeps it progressive, the first indication for its treatment is its optical correction, that the patient may have distinct vision to induce him to turn his attention toward distant objects, and to free him from the necessity of excessive convergence.

The correcting glasses for myopia should be worn constantly. Wearing them only for distant vision greatly lessens their usefulness. It is most important for a young person to use the correcting lenses constantly, so that in the requirements made on accommodation he shall have a constant check to excessive convergence. The fear that accommodation may prove injurious has frequently led to the use of a partial correction only for near work. This rarely proves permanently satisfactory. Convergence to a near working point without some accommodation is impossible; and this accommodation makes it necessary to bring the object still closer and further tax the convergence.

The fear that normal accommodation is bad for a myopic eye has led to the prescription of lenses strong enough to greatly improve distant vision, yet weaker than the full correction. Such lenses may be very dangerous to the myopic eye. Looking obliquely through them increases their effect and renders dis-

tant vision more distinct. The patient discovers this and avails himself of it. But looking obliquely through a lens gives, besides the increased power of the spherical, the effect of a cylindrical element and aberration, which vary with the direction and amount of obliquity, and which subject the eye to a strain similar to that caused by uncorrected astigmatism—a strain all the harder upon the eye because it is inconstant. Glasses which may be made thus to approximate the full correction for myopia are the most dangerous that can be worn. Yet because their use has often resulted disastrously many surgeons hesitate about giving the stronger lenses of a full correction, although these would be really free from such a danger. If for any reason something less than the full correction is given, it should be carefully considered whether its use is liable to be thus perverted and cause injury.

The general rule is, *in myopia give correcting lenses for constant use*. To this there are certain exceptions. With presbyopia it becomes necessary to give weaker lenses for near work. Again, when binocular vision has been given up, strain of convergence, the chief indication for the use of correcting lenses, is removed, and a full correction may induce a renewed effort of convergence to restore binocular vision. On this account it will generally be better not to give a correcting lens for the worse eye. Persons who have reached middle age or later life without the use of lenses often find it difficult or impossible to become accustomed to them. Improved vision will often not compensate for the discomfort and inconvenience given, so that these cases must be made exceptions. With very high myopia a lens slightly weaker than the full correction gives an image more like that to which the patient has been accustomed, and which is, therefore, preferred. When this is the case, there is no temptation to get an increased effect by looking obliquely through the lens. Some persons object to the diminished retinal images caused by strong concave lenses, and prefer very much weaker lenses. If one weak enough to entail no strain when looking through it obliquely answers the purpose without any risk of excessive convergence, it may be wiser to give it. Occasionally, too, the full correction may be given for distant vision, and something deducted (1 or 2 D.) from the glass for near work, until the habit of accommodating normally for near objects has been formed. Patients should be warned of the dangers of looking obliquely through concave glasses.

Besides using correcting lenses, the myope must learn to keep his near work as far from his eyes as possible. The lenses are chiefly useful by enabling him to have a greater working distance, and no benefit as regards the progress of the myopia or the health of the eye can be expected unless the opportunity to diminish the strain of convergence is utilized. As an aid to a greater working distance, good light and the avoidance of reading very fine print or prolonged looking at other minute objects must be attended to. Care must be taken to avoid protracted near work. It should be interrupted by frequent intervals, during which the convergence may be allowed to relax and the eyes to fix on some distant object. The position of the head is also important, particularly in young persons. Reading while lying down or in a bent posture, causing pressure on the veins of the neck, favors ocular congestion, and should especially be avoided. Use of the eyes during periods of impaired nutrition, as from acute disease, during great physical exhaustion, etc., may also be dangerous. Outdoor life, besides demanding distant rather than near vision, acts by improving general nutrition. When choroidal congestion is marked, the influence of complete rest of the eyes for some days under the influence of a mydriatic may promptly check a process that tends

to soften and rapidly distend the sclera. When increase of myopia does occur the lenses should be promptly changed accordingly.

The *operative treatment of myopia* by removal of the crystalline lens by discission, followed by extraction if the patient's age makes it necessary, is claimed not only to improve vision by removal of high myopia, making comparatively weak glasses necessary, but also to exert an influence in checking the progress of the myopia, and actually to cause a diminution in the antero-posterior axis of the eyeball. In the judgment of the writer it is not proper to resort to it in any case where the progress of the myopia can be arrested by the wearing of correcting lenses and ordinary hygienic precautions. But where glasses cannot be comfortably worn or with them the myopia continues distinctly progressive, it is proper to extract the crystalline lens. This operation may also be resorted to in cases of high myopia in one eye and in myopia with commencing lens opacity. In such eyes cataract often remains incomplete for many years, and grows no easier of extraction—it may even become more difficult to remove because of the larger nucleus when ripe than when the opacity begins to interfere with vision. The reduction in myopia by extraction of the lens varies in different eyes, usually between 15 and 20 D. Generally, it will not be exactly corrected by the removal of the lens; glasses for both near and distant vision will be required, accommodation being lost with the removal of the lens.

Astigmatism.—Its Nature and the Vision of Astigmatic Eyes.—*Astigmatism is always an ametropia of curvature. It is a defect in which rays from a single point do not after refraction tend to meet at a single point.*

In *irregular astigmatism* the curvature is irregular and the refraction differs in the different parts of the pupil.

In *regular astigmatism* the refraction is the same in different parts of the pupil, but differs at the same point in different directions. This depends upon inequality of curvature of the dioptric surfaces in the different directions.

A familiar illustration of the kind of surface causing it is found in the curve of the edge of a watch. The curve in the plane parallel to the face of the watch is weaker than the curve in the plane perpendicular to the face. The inequality of curvature causes the rays to be refracted more strongly in the direction of the stronger curve, and in that plane to come to a focus before they have reached a focus in the plane of the weaker curve. Instead of being focussed to a single point, they are focussed successively to two lines at right angles to each other and separated by a certain interval.

In most cases of regular astigmatism the fault depends chiefly upon inequality of curvature in the cornea, although there is usually also some inequality in curvature in the crystalline lens. It is common to speak as though the astigmatism were due entirely to the corneal curvature, but it should be remembered that this is only exceptionally the case.

In considering the refraction of the astigmatic eye it is only necessary to follow the course of the rays as regards two meridians, called the *principal meridians*—viz. the meridian of greatest curvature or greatest refraction, and the meridian of least curvature or least refraction. In regular astigmatism these are always perpendicular to each other. In some eyes they are not perpendicular, but in such eyes the astigmatism is not regular, or if a part of it be regular, there is present also some irregular astigmatism, which cannot be corrected by any lens. (See page 206.) When the refraction has been corrected in the principal meridians all of the regular astigmatism, all the astigmatism that is corrigible, is corrected for all meridians.

The focussing of light by the astigmatic eye may be illustrated by Fig.

161, in which the circle represents the cornea as seen from the front; $a a$ represents the principal meridian of greatest refraction, and $b b$ the principal meridian of least refraction. By the vertical curvature all rays entering the upper half of the cornea are brought down to the level of the central ray when they reach the point f , and all rays entering the lower half of the cornea are brought up to the central ray at the same point. At f all the rays have

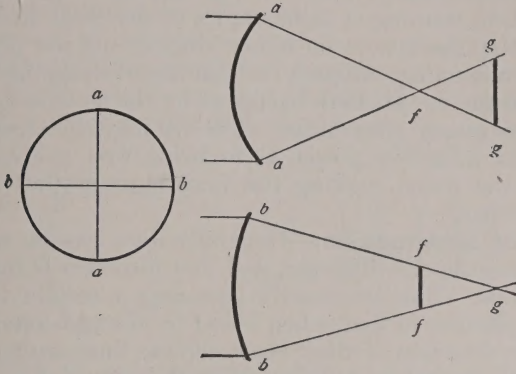


FIG. 161.—Illustrating the refraction of the rays in the principal meridians.

been brought to the level of the central ray, but they have not been focussed to a point, for in the meridian of least refraction, $b b$, they have been less turned from their original course, and therefore from side to side are still spread out the distance $f f$. Not until they have travelled on to the point g are those from the right half of the pupil and from the left half of the pupil all collected to the center line of the pupil. By the time they have been thus collected from side to side they have begun to spread downward and upward, so that they occupy vertically the distance $g g$. A horizontal line, $f f$, into which all the rays are collected, is the focus for the vertical meridian, the *first focal line*; and $g g$, a vertical or *second focal line* in which all these rays are afterward collected, is the focus for the horizontal meridian or horizontal curvature of the cornea. The interval between $f f$ and $g g$, depending on the difference of curvature in the directions $a a$ and $b b$, called the *focal interval of Sturm*, shows the amount of astigmatism.

To f and g the rays from a single point outside of the eye are collected,

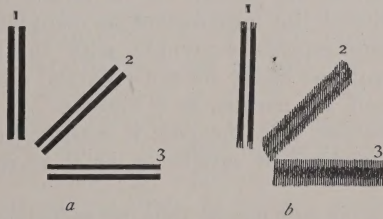


FIG. 162.—Illustrating the appearance of lines running in different directions as seen by (a) the normal eye and (b) the astigmatic eye.

forming at each a focal line; at all other distances behind the cornea they spread out, making an area of diffusion which is commonly an ellipse, though at one point between f and g it becomes a circle. The focussing of the rays from a point outside of the eye upon a line of the retina gives rise to the peculiar defect of vision produced by astigmatism. This defect is such that

lines running in the direction of the focal line on the retina are seen clearly, except that their ends shade off gradually, but the lines running in other directions appear blurred, as in Fig. 162.

a represents lines running in three directions, as seen by an emmetropic eye. *b* represents the impression such lines make on the retina of an astigmatic eye: 1 shows them running in the direction of the focal lines on the retina, so that these overlap each other, giving the impression of a distinct line; 3 shows them running at right angles to the focal lines on the retina, so that they overlap the spaces on either side, giving the greatest blurring; and 2 shows them running obliquely, so that the overlapping causes blurring, but less than that for 3. All lines looked at by the astigmatic eye are seen in one of these ways at any given time. The eye may, by change of accommodation, so vary its refractive power as to bring first one and then another focal line upon the retina, making the lines clear at first in one direction and then in the other.

Symptoms of Astigmatism.—Generally lines can be seen clearly only when they run in some one direction, and this direction is that of one of the principal meridians. This necessarily occasions a certain indistinctness of vision, which is peculiar in that, when tested by the test-letters, some of these on account of the direction of their characteristic lines are more blurred than others. The patient may miscall several of the letters of a certain size, and yet recognize others of but half that size. In general, the indistinctness due to astigmatism is not more than half as great as that produced by myopia or hyperopia of equal amount.

It has been stated that the astigmatic eye seeks to overcome indistinctness of vision by unequal contraction of different parts of the ciliary muscle, causing unequal convexity of the crystalline lens in different meridians. It has not been certainly proved that this occurs. But the indistinctness may be partly overcome by rapid changes from one state of accommodation to another, causing first the one focal line and then the other to fall upon the retina in such quick succession that their impressions may aid in a single mental perception. Either use of the accommodation leads to eye-strain with all its possible manifestations—pain, congestion or inflammation of the eye and its appendages, headache, and other manifestations of disturbance of the general nervous system. In childhood the difficulty of the imperfect images hinders the development of the powers of visual perception, and even of the general mental processes. Indistinctness of vision, though present from early life, may somewhat diminish as the patient learns to use his eyes, but increases again when age has caused the impairment or complete loss of accommodation. High astigmatism, especially myopic, with the greatest defect in the vertical meridian, is quite as likely to cause partial closure of the lids, with secondary disturbances of the cornea, as is myopia.

Varieties.—*Astigmatism with the rule* is astigmatism with the meridian of greatest refraction vertical or nearly so, as it is in a large majority of cases.

Astigmatism against the rule means that the meridian of greatest refraction is horizontal or nearly so. The number of cases of this kind is comparatively small, but they grow more frequent after middle life. The astigmatism that follows cataract extraction, iridectomy, and similar corneal sections is usually of this kind, because such sections are generally made in the upper margin of the cornea, and their influence is to flatten the cornea in the meridian perpendicular to their length. Astigmatism against the rule has also been noted as a forerunner of glaucoma.

Oblique astigmatism means that the direction of the principal meridians departs much from the vertical and horizontal, and approaches rather to 45 and 135 degrees. Some writers believe that astigmatism against the rule and oblique astigmatism are most likely to cause inconvenience, or to cause more inconvenience than astigmatism with the rule of equal amount. This may be explained by the fact that only lines parallel to the principal meridians can be perfectly focussed on the retina, and that the greatest number of lines looked at are either vertical or horizontal.

While the amount of astigmatism and the direction of its principal meridians are independent of the position of the retina, the relation of the retina to the focal lines determines the variety under which astigmatism is classified; thus, in Fig. 163, suppose c represents the cornea, the solid lines represent

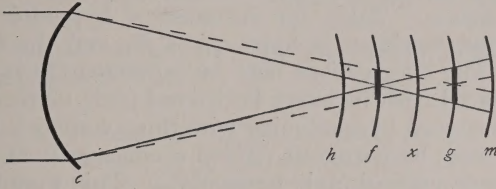


FIG. 163.—Figure illustrating varieties of astigmatism.

rays as refracted in the vertical meridian, and the broken lines the rays as refracted horizontally, f to be the position of the anterior focal line, and g the position of the posterior focal line. When the retina passes through f the defect is called *simple hyperopic astigmatism*—hyperopic because as regards the meridian of least refraction and the focal line g the eye is hyperopic—simple because it can be corrected by the simple cylindrical lens which corrects the meridian of least refraction.

When the retina is situated at h the astigmatism is called *compound hyperopic*. The eye is hyperopic for both meridians, for both focal lines, and it can be corrected only by a compound cylindrical or sphero-cylindrical lens.

When the retina passes through g the defect is *simple myopic astigmatism*, the eye being myopic for the meridian of greatest refraction and the focal line f , and capable of correction by a simple cylinder correcting the meridian of greatest refraction.

When the retina is at m the astigmatism is *compound myopic*, the eye being myopic for both focal lines and meridians, and its ametropia is only corrected by a compound cylindrical or sphero-cylindrical lens.

When the retina is situated between f and g the eye is hyperopic for g and the meridian of least refraction, and myopic for f and the meridian of greatest refraction; the astigmatism is called *mixed*, and requires for the correction of the ametropia a lens convex in one meridian and concave in the other. It is evident that simple increase in the antero-posterior axis of the eyeball by distention will cause the same case of astigmatism to pass from compound hyperopic to simple, then to mixed, afterward to simple, and finally to compound myopic. In case of astigmatism becoming myopic these changes successively occur in the course of the progressive distention of the eyeball (see also pages 127 and 128).

Correction of Astigmatism.—This is effected when rays, instead of being focussed to two focal lines, are focussed to a single point. The correction of the ametropia present requires that for parallel rays this point shall fall upon the retina. But the astigmatism may be fully corrected, although a certain

amount of other ametropia (hyperopia or myopia) remains uncorrected. Astigmatism is corrected by any cylindrical lens or combination of lenses that makes up for the difference of refraction in the two principal meridians. Thus a convex cylinder with its curve parallel to the meridian of least refraction, and equal in strength to the difference between the two principal meridians, will correct any case of astigmatism. A concave cylinder with its curve parallel to the meridian of greatest refraction, and strong enough to make the difference between the two meridians, will correct it equally well. Or a convex cylinder correcting a part of the astigmatism may be placed with its curve in the direction of the meridian of least refraction, and a concave cylinder strong enough to correct the remainder of the astigmatism with its curve parallel to the meridian of greatest refraction.

In general, any case of astigmatism may be corrected by one of three combinations of lenses. Take, for instance, a hyperopic astigmatism in which the horizontal meridian is hyperopic 4 D., and the vertical meridian hyperopic 2 D. The astigmatism may be corrected (1) by a convex 2 D. cylindrical lens placed with its curve horizontal (axis vertical), and the additional hyperopia corrected by combining with this a convex 2 D. spherical lens. This astigmatism may be corrected (2) by a concave 2 D. cylindrical lens placed with its curve vertical (axis horizontal). This would have the effect of increasing the hyperopia of the vertical meridian, and to correct the hyperopia a convex 4 D. spherical lens would be required. It would also be possible (3) to correct the astigmatism with a convex 4 D. cylinder with its curve horizontal (axis vertical) and a convex 2 D. cylinder with its curve vertical (axis horizontal). The one cylinder would bring the posterior focal line on the retina without affecting the anterior focal line, and the other cylinder would bring the anterior focal line on the retina without affecting the posterior line. In this way both focal lines, brought to the same distance from the cornea, would become a single point, and the astigmatism would be corrected, and with it also the hyperopia.

For the one case of astigmatism any of the following lenses might be chosen, the correction being optically as good with one as with another :

- (1) + 2 D. sph. $\odot$ + 2 D. cyl. axis 90° (vertical) ;
- (2) + 4 D. sph. $\odot$ - 2 D. cyl. axis 180° (horizontal) ;
- (3) + 2 D. cyl. axis 180° $\odot$ + 4 D. cyl. axis 90° .

Looking at these, it will be seen that (1) has on the whole the weakest surfaces. It is theoretically possible with it to get the thinnest lens and the one having usually the least aberration. It is also the lens most commonly selected in testing the eye with trial glasses, and the one most frequently prescribed.

It will be observed that (2) has one convex and one concave surface. The spherical surface has to be stronger than that of (1), and therefore causes more aberration ; but this is a matter of very little importance. It is of greater importance that by placing the concave surface toward the eye and the convex surface away from it something of a *periscopic* effect can be obtained by this second lens allowing the eye to be turned in different directions without causing so much obliquity of the visual axis to the lens surfaces. On this account (2) will prove on the whole the most satisfactory for a large proportion of cases.

With reference to (3), it will be noted that it includes two cylindrical surfaces with their axes exactly perpendicular. Such a lens is very hard to

grind sufficiently accurate for practical purposes, and impossible to grind with theoretic accuracy. Its surfaces, too, are stronger, and therefore cause more aberration. On every account this form of lens, the *crossed cylinder*, is to be avoided. It has rarely been used except for mixed astigmatism, where it gives weaker surfaces than either of the sphero-cylindrical lenses. But this does not compensate for the increased expense and necessary inaccuracy of crossed cylinders, and it is better never to employ them.

The following formulas will illustrate this subject as regards mixed astigmatism :

- (1) $-1 \text{ D. sph. } \odot + 2 \text{ D. cyl. axis } 90^\circ$;
- (2) $+1 \text{ D. sph. } \odot - 2 \text{ D. cyl. axis } 180^\circ$;
- (3) $+1 \text{ D. cyl. axis } 90^\circ \odot - 1 \text{ D. cyl. axis } 180^\circ$.

In compound myopic astigmatism the same thing holds, as the following equivalent formulas will indicate :

- (1) $-2 \text{ D. sph. } \odot - 2 \text{ D. cyl. axis } 180^\circ$;
- (2) $-4 \text{ D. sph. } \odot + 2 \text{ D. cyl. axis } 90^\circ$;
- (3) $-4 \text{ D. cyl. axis } 180^\circ \odot - 2 \text{ D. cyl. axis } 90^\circ$.

In simple astigmatism the correction for the better meridian is 0 ; and one element of formulas (2) and (3) becomes 0, so that the two become alike. In simple hyperopic astigmatism we would have the following :

- (1) or (3) $+2 \text{ D. cyl. axis } 90^\circ$;
- (2) $+2 \text{ D. sph. } \odot - 2 \text{ D. cyl. axis } 180^\circ$;

from which one may choose the simple cylinder, which is the cheapest lens, or the sphero-cylindrical lens, which gives the better periscopic effect.

In simple myopic astigmatism the formulas are thus :

- (1) or (3) $-2 \text{ D. cyl. axis } 180^\circ$;
- (2) $-2 \text{ D. sph. } \odot + 2 \text{ D. cyl. axis } 90^\circ$.

Wearing Glasses for Astigmatism.—The whole treatment of astigmatism consists in the wearing of glasses. Since astigmatism interferes with distinctness of vision at all distances, and since it entails, when uncorrected, a use of the accommodation entirely different from that of emmetropic, hyperopic, or myopic eyes, it is important that the lenses correcting it should be worn constantly. This is essential in all cases at first. Sometimes a patient, by wearing glasses constantly acquires the habit of using the accommodation normally and can continue to so use it by sacrificing something of distinctness of vision on laying aside his correcting lenses at times when the eyes are not to be especially taxed. Such persons, after the constant use of cylinders for some time, are able to do without using them constantly when the eyes are not employed on work requiring distinct vision. In general, however, a patient having much astigmatism may be warned that he will always require the help of correcting lenses.

Cylindrical lenses, contrary to what is sometimes expected, are often difficult to become accustomed to, especially if they are strong, if the patient is advanced in years, and if the axes of the cylinders before the two eyes must be turned in different directions. Strong cylinders are never satisfactory at

first. With some persons, especially when past middle life, the difficulty of becoming accustomed to them is so great that they are very likely to give up the attempt. This should be carefully considered before ordering glasses. Any cylindrical lens changes somewhat the shape of the retinal images and, therefore, the apparent shape of objects looked at. When the axes are turned in different directions the distortion of the retinal images, corresponding to the directions of the axes, differs in the two eyes, so that it becomes difficult to fuse the two impressions they make and secure binocular vision. These unpleasant effects may be diminished by wearing for a time an incomplete correction of the astigmatism or by bringing the lenses particularly close to the eyes.

Aberration.—A spherical lens does not perfectly focus the rays passing through it. In general it acts toward the edge as a stronger lens. This may be illustrated by the following diagram, which shows the course of the parallel rays as refracted by a convex spherical surface (Fig. 164). The rays passing through the center are focussed at f , the principal focus of the lens, and those passing through the margin are focussed closer to the lens. The unequal distribution of light in the circle of diffusion, its concentration to a

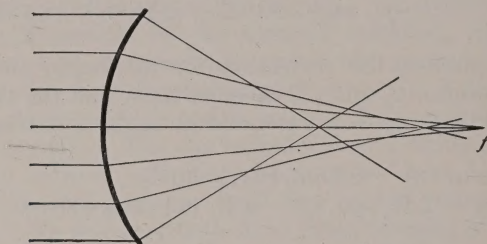


FIG. 164.—Figure illustrating spherical aberration.

ring at the edge and a point at the center of that circle, may be studied with a strong convex lens focussing light upon a card.

In the human eye the periphery of the crystalline lens is more convex than the center, and acts, therefore, as a stronger lens than the center, just as in the ordinary spherical lens. The periphery of the cornea, on the other hand, is always more or less flattened. Within the pupil, in the majority of eyes, the increased convexity of the crystalline lens predominates, so that they present a stronger refraction, higher myopia or lower hyperopia, at the periphery of the pupil than at its center. This condition the writer has called *positive aberration*. When the opposite occurs the refraction is stronger, the myopia higher or the hyperopia lower at the center of the pupil than near its margin, constituting *negative aberration*.

Aberration plays an important part in skiascopy, determining the form and size of the light area in the pupil, causing reversal of the movement of light in the periphery (in positive aberration) to be perceived closer to the eye than the movement of light at the center, where it is of more practical importance.

When aberration is confined chiefly to the extreme periphery of the pupil, where it is shut off by the pupillary contraction in a strong light or during near work, it has no influence on the working power of the eye. When it begins near the center of the pupil, causing the eye to be more hyperopic when the pupil is contracted by a strong light or for close work than when more dilated, it has an important influence in producing eye-strain, and may

be a cause of error in the selection of lenses. An eye with positive aberration will often select with the undilated pupil a convex lens 0.25 D. stronger, or a concave 0.25 D. weaker, than it will accept while the eye is fully under the mydriatic.

Aberration is to be recognized by skiascopy and considered in the choice of lenses. It cannot be exactly corrected by any particular lens, but is sometimes an indication for the wearing of a stronger lens than one which will allow of perfect distant vision, such a lens being found in these cases decidedly more helpful. High negative aberration is sometimes due to increased refractive power in the nucleus of the lens—incipient senile cataract—or to conical cornea.

Irregular astigmatism is recognized by skiascopy, causing appearances represented in Fig. 165 *A* and *B*. Traumatism or disease of the cornea, leaving irregularities of its surfaces (Fig. 165, *A*), tissue-changes in the lens preceding cataract (Fig. 165, *B*), and occasionally faulty development of the cornea or lens, cause irregularities of refraction that prevent the perfect focussing of light to a point by the dioptric media. Such defects are not capable of correction by lenses. The eye, however, often presents within the area of the pupil small areas in which the refraction is comparatively uniform, which areas may be corrected by some combination of lenses, and the vision and comfort of the

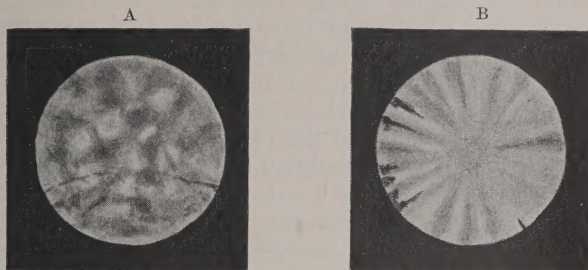


Fig. 165.—Appearances of irregular astigmatism recognized by skiascopy.

patient thus be greatly improved. The practical thing to do is to study these cases carefully by ophthalmometry and skiascopy, and to correct the most regular portion of the cornea.

In a few cases, where no lens can render much service, it may be worth while to try a *stenopaic spectacle*. This is an opaque disk in front of the eye with a narrow slit or, more commonly, a single pin-hole opening in it. Such an apparatus often gives a noticeable improvement of vision, but it is rarely found very serviceable because it interferes with the visual field.

Anisometropia.—Some inequality in the refraction of the two eyes is the rule, and occasionally this is such as to render one eye hyperopic and the other myopic, or one astigmatic, while the other is free from astigmatism. Such a difference constitutes *anisometropia*. The importance of the difference depends entirely on its degree, and not on whether it amounts to a difference in the kind of ametropia.

The general rule when the difference is not great is to give each eye its exact correction. If the difference between the two correcting lenses is very great, they affect the size of the retinal images, so that binocular vision becomes difficult. When one lens is much stronger than the other, looking through the periphery produces a correspondingly different prismatic effect, causing objects to be seen double, or the effort to use the images falling on the two retinas causes strain of the extraocular muscles.

For the above reasons the full correction of anisometropia cannot always be practised. It is generally safe to prescribe the correcting lenses for both eyes when these differ less than 1 D. If they differ not more than 2 D., they will generally be accepted, although this cannot always be assumed. If they differ more than 2 D., the patient will find it very difficult or impossible to use them for satisfactory binocular vision, although a few persons will prefer to have anisometropia of 3 or 4 D. fully corrected. When the difference of refraction cannot be fully met by difference of glasses, the rule is to correct the better eye and to allow the worse eye the full correction of its astigmatism, with a spherical lens equal to that of the better eye or a little stronger. Sometimes, if both eyes have good vision, but cannot work together, one may be corrected for distant vision and the other given a lens that will adapt it for near seeing. Congenital anisometropia often gives little trouble, but anisometropia coming on from change in the refraction, as in progressive myopia, is likely to be very annoying. The similar effect produced by glasses not accurately suited to the eyes is also very annoying. Acquired anisometropia, particularly from 0.5 to 2 D., is especially liable to give rise to squint, and its correction is indicated to preserve or restore binocular vision.

Presbyopia.¹—The failure of accommodation with age leads finally to complete inability to change the optical condition of the eye, so that only rays of a certain convergence or divergence can be focussed upon the retina. In the great majority of eyes, which are hyperopic, this renders necessary the use of convex lenses for near vision. For this purpose the need of lenses is felt—the eye is presbyopic—as soon as the power of accommodation has diminished so that it is unequal to the task of keeping the crystalline lens convex enough to focus rays accurately on the retina when the eye is engaged in ordinary near work. When this occurs either symptoms of strain, such as congestion and pain in the eye, conjunctivitis,* or headache, arise, or after the effort has been sustained for some time the ciliary muscles suddenly relax and all near objects become blurred. If the eyes are now rested for a minute, the power of distinct near vision returns, but if the near vision is continued, it again fails, and, persisting in the attempt, such failures become more and more frequent until the effort is given up.

The failure is first for objects at the shortest distance from the eye, as small objects or fine print that needs to be brought close in order to be seen. Objects that may be held farther away, or the same object in a strong light which will render it distinguishable at a greater distance, may still be clearly seen, the patient noticing only that he requires good light and has to hold things farther from the eyes than formerly. Presbyopia is caused first by the increasing rigidity of the crystalline lens, which limits its tendency to become more convex when the tension of the suspensory ligament is removed by contraction of the ciliary muscle. Subsequently the ciliary muscle also becomes weakened or undergoes atrophy, and the power of accommodation is completely lost.

Presbyopia is relieved by supplementing the insufficient focussing power of the crystalline lens by a convex lens of the necessary strength placed before the eye. In choosing such a lens it is to be borne in mind that we have to enable the eye not only to see clearly at the required distance for an instant, but to sustain distinct vision at that distance over periods of continuous use. The maximum contraction of a muscle is always one that cannot be long sustained; hence the lens giving the patient a near point where he wishes to

¹ For additional consideration of this subject see page 137.

work will be insufficient for continuous work. With most persons only two-thirds of the accommodation can be long kept up. A few can sustain three-fourths of it, but others, particularly young persons suffering from weakness of accommodation, can comfortably sustain only one-half of the full amount.

In correcting presbyopia, then, we not only find the near point of distinct vision, but from that near point and the refraction of the eye calculate the total power of accommodation. Then assuming that two-thirds of this accommodative power is available for continuous work, the difference between that available accommodation and the accommodation required for the sort of near work to be done is the strength of lens that should be given to correct the presbyopia. This may be illustrated by examples of different errors of refraction.

Suppose, first, a case of presbyopia in emmetropic eyes. The nearest point of distinct vision being 18 inches (45.5 cm.), corresponding to 2.25 D. of accommodation, two-thirds of this, which may be assumed as available for near work, equals 1.5 D. Now, if the patient wishes to use the eyes for ordinary reading, writing, sewing, etc. at a distance of 13 inches (33 cm.), where 3 D. of focussing power will be required, $3 - 1.5 \text{ D.} = 1.5 \text{ D.}$ will be the strength of the convex lens that should be given to supplement accommodation—to correct the presbyopia. If the patient has been wearing such a lens or one nearly as strong, and still shows evidence of undue strain of the eyes for near work, it may be that he cannot sustain two-thirds of his total accommodation, but requires the presbyopic correction to be made somewhat stronger, as 1.75 or 2 D. On the other hand, if such a patient has been reading without any lens and without much inconvenience, it may be assumed that he can sustain more than two-thirds of his total accommodation, and therefore a weaker lens, as the 1 or 1.25 D., may be given.

Suppose in another case the patient has hyperopia of 2 D., and a near point of distinct vision of 16 inches (40 cm.), corresponding to 2.5 D. of focussing power, to which is added the 2 D. needed to correct the hyperopia, making 4.5 D. of total accommodation. Two-thirds of this accommodation, or 3 D., would only correct his hyperopia, and leave 1 D. to adapt the eye for near vision at a distance of 1 m. If such a patient is to work at 13 inches (33 cm.), where 3 D. of focussing power is needed, he will require the help of a lens equal to 3 D., -1 D. , or 2 D. The increased use for accommodation will cause the hyperopic eye to suffer earlier from presbyopia if it has not the help of correcting lenses for the hyperopia. It will also be noted that with a certain near point the hyperopic eye requires a stronger supplementary lens, since that near point represents, with a greater amount of accommodation, a greater need for it. The lens required in the above case might be found by correcting the hyperopia with a 2 D. convex lens, when it would be found that the near point was at 9 inches (23 cm.) (4.5 D. of accommodation), and that two-thirds of this accommodation, 3 D., would be sufficient for work at 13 inches (33 cm.). Hence no further correction for presbyopia would be required, the correction of the hyperopia causing the presbyopia to disappear.

By myopia the need for a presbyopic correction is postponed and diminished. Thus, an eye with myopia of 3 D. will be able to work at 13 inches (33 cm.) without any lens and without accommodation, and for that kind of work will never suffer from presbyopia. Take another case, where the myopia is 1 D. and the near point found at 22 inches (57 cm.), corresponding to 1.75 D. of focussing power; subtracting from this 1 D. of myopia leaves 0.75 D. as the

total accommodation. Of this two-thirds, or 0.5 D., being available for near work, is to be added to the 1 D. of myopia, making 1.5 D. of available focussing power, and for work to be done at 13 inches there will be need in addition for a convex lens of 1.5 D. That is, in myopia of 1 D., with only 0.75 D. of accommodation, the same help is required as in emmetropia with accommodation of 2.25 D. With myopia, as with hyperopia, the total accommodation may also be found by first correcting the myopia and then taking the near point.

In astigmatism the accommodation can only be accurately determined by taking the near point after the correction of the astigmatism, and the amount of convex spherical to be added for near work on account of presbyopia will then be determined as though the eye had been originally emmetropic. Sometimes in giving lenses for presbyopia with astigmatism, while the concave cylinder is better for distance, the convex cylinder with its axis turned at right angles is better for near work. Suppose a case of simple myopic astigmatism requires for its correction — 1.5 D., cylinder axis 180° , and with this correction before the eye the near point is 18 inches (46 cm.), the accommodation 2.25 D. The spherical to be added for near work at 13 inches (33 cm.) would be 1.5 D., and a convex 1.5 D. spherical, combined with the concave 1.5 D., cylinder axis 180° , is the optical equivalent of the convex 1.5 D., cylinder axis 90° . For distant vision such an eye may be given — 1.5 D., cylinder axis 180° , and for near vision + 1.5 D., cylinder axis 90° .

Course.—Presbyopia usually begins between the ages of forty and fifty. With hyperopia, which may have given no earlier evidence of its presence, it begins younger; with myopia, later or not at all. Even with emmetropic eyes the increasing rigidity of the lens may require the use of convex glasses before the age of forty, and with a few the need of a presbyopic correction is deferred until after the age of fifty.

In all cases after it has begun presbyopia is progressive. The power of accommodation continues to diminish until it is entirely lost, and such diminution causes the necessity for increasing the strength of the supplementary lenses—the presbyopic correction. Generally, the lenses should be changed often enough to have a difference of not more than 0.75 D., or about once every two or three years from forty-five to fifty-five. Most patients require the same correction for presbyopia for both eyes. In a few cases this is not so, the accommodation failing faster in one eye than in the other, and requiring a correspondingly stronger supplementary lens. In such cases the eyes should be repeatedly tested to make sure that there is actually a difference between them, and the tests repeated at short intervals.

The Mounting of Glasses.—Lenses are commonly supported before the eyes by spectacle or eye-glass (pince-nez) frames. The former have the advantage of more rigidly fixing the position of the lens before the eye. The latter are more readily removable when the lenses are not required for constant use. The proper adjustment of the frames is a matter of much importance, since the right lens in the wrong position does not have its proper effect, and may be entirely unsatisfactory (see pages 236–240).

The Period of Adaptation.—Weak lenses, less than 1 D., may prove satisfactory and comfortable from the start or within a few days after beginning to wear them. Children may become accustomed to even strong lenses in a very few days. Correcting lenses will generally be accepted without complaint when the eye is kept for some time under the influence of a mydriatic. But, apart from these exceptions, lenses are rarely accepted with entire comfort at first.

The period of adaptation during which the first discomfort diminishes and passes away may last from two to six weeks, or even longer; during this period convex lenses are likely to cause blurring of distant vision, concaves render near work noticeably more fatiguing, and cylinders cause distortion of objects and an indefinite discomfort. These unpleasant effects may from the start be more than balanced by the benefits experienced, yet it is prudent in all cases to warn the patient that some weeks must elapse before the glasses can be expected to do their best. With such a warning most people encounter the necessary difficulties without loss of confidence. But if permitted to put on the glasses expecting immediate satisfaction, they become disappointed, lose faith in the prescriber, and are likely to refuse to give them a fair trial. The good of the patient and the reputation of the surgeon both demand that a careful explanation of the period of adaptation should be given when the glasses are prescribed.

SPECTACLES AND THEIR ADJUSTMENT.

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A SPECTACLE-LENS should be so placed that, in use, the line of sight passes through the optical center perpendicular to the plane in which the glass lies. These simple conditions would be extremely easy to satisfy were it not for the fact that the organ of vision must of necessity be extremely active and mobile. The eyeball may, in fact, be rolled in its socket about 60° in every direction from a point immediately in its front, while movements of the head, or even of the entire body, are constantly called in requisition as greater range of vision is required. These facts destroy at once the possibility of so placing a glass that its center may be coincident with, and its plane be perpendicular to, the line of sight under all circumstances. Only a glass fastened to the eye and moving with it could fulfil these conditions.

Though the glass cannot be attached to the eye, it can be and is attached to the head, which, as has been noted, is nearly constantly in motion, seconding the activity of the eyes. The necessity of looking through the center of the glass limits for the wearer the range of the eyes in their sockets, and increases in a corresponding degree the excursions made by the head. This augmented head-motion, which can be noticed in almost all wearers of glasses, arises partly also from the effort to bring the plane of the lenses perpendicular to the line of sight. The only exception to these statements is in the case of a person who is wearing a glass which under-corrects his ametropia, and who looks through it obliquely in order to increase its refractive effect. The more exactly the glass and frame are fitted to the requirements of the case, the less of this auxiliary head-movement will be required; some increase in it must, however, be accepted as one of the concomitants of wearing spectacles. When a person with glasses raises his head continually, markedly elevates or depresses his chin, or forcibly twists his spectacle frame in his fingers, he is instinctively seeking to correct faulty refraction or faulty frame-fitting.

Spectacles are ordered to be worn either constantly, or for near work only, or for distant vision only. It will be readily understood that the circumstances under which near work is usually done admit of the most exact adjustment of the glass. Such work is usually held in the hands or occupies a desk or bench having a fixed position relative to the workman. It is below the level of his eyes and within reach of his hands, and only slight excursions of the eyes are required in its performance. As the line of sight is directed downward, the "near" glass (*n*, Fig. 166) must be placed below the level of the eye; at least its optical center must be so placed. It must face strongly downward in order to bring its plane perpendicular to the line of sight (*b*). It should face slightly inward for the same purpose, since the visual axes converge in near vision. This convergence necessitates, further, that the optical centers of the glasses shall be placed from 4 to 6 mm. nearer together

than are the centers of the pupils, since the visual axes would otherwise pass to their inner sides. If an isosceles triangle is constructed with the interpupillary distance as its base, and the visual axes, directed toward a near object, as its remaining sides, it will be apparent that the farther from the eyes a pair of glasses stand and the nearer to the eyes the work is situated, the less should be the distance between the optical centers of the glasses. The precise distance between optical centers which any given case may require may thus be determined.

In "distant" vision the gaze may be directed toward any point of the horizon or firmament, and yet, practically, the relation of the line of sight to the face, and consequently to glasses attached to the face, does not vary greatly. A distant object would have to change its position considerably in order to move through five degrees of one's field of view. Hence rapid changes in the direction of the line of sight are seldom required. Ample time is afforded for whatever adjustments of the head and trunk may be necessary. Distant vision usually takes place, therefore, with the visual axes directed forward perpendicular to the plane of the face (*a*, Fig. 166).

When glasses are ordered for this use alone they should have optical centers separated by the same interval as that between the pupils (since they will not be used during convergence), and should face directly forward, lying in a plane parallel to the general plane of the face (*d*, Fig. 166). The optical centers of the lenses should stand at the same height as the pupils.

In the greater number of cases the spectacles prescribed are intended for constant use—that is, the wearer will need them as well in viewing distant objects as in work near at hand. It is evident that to place the lenses in the exact position desirable for either of these purposes would render their use awkward for the other. In the height of the optical centers as well as in their distance from each other, and in the facing of the glass, we are therefore forced to place "constant" glasses in a position intermediate between that best for distant vision and that best for near work. This intermediate position is selected, not at all because these glasses are used at an intermediate distance, but because from this position they may be readily shifted, at least approximately, by a motion of the head into either of the other positions. The distance between the optical centers of "near" glasses should be from 4 to 6 mm. less than are the centers of the "distant" glasses intended for the same patient. This dimension is, of course, unaffected by movements of the head. Nevertheless, in order to reduce the unavoidable discrepancy to the minimum, the distance between the centers of the "constant" glasses should be 2 or 3 mm. less than that proper for the "distant" glasses. By a similar concession the "constant" glass is faced moderately downward and its centers placed somewhat lower than those of the "distant" glass, but not so low as those of the "near" glass.

In this connection the occupation of the patient should be considered. A seamstress or bookkeeper, for instance, if wearing a glass constantly should have it adjusted almost like a "near" glass, while persons engaged in outdoor

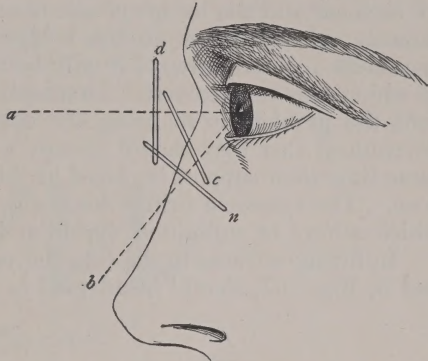


FIG. 166.—Showing position of lenses before eye.

occupations will require an adjustment much nearer that proper for a "distant" glass.

The greater the strength of the prescribed lens the more necessary is attention to these details, since the effect of slight obliquity of the lens to the visual axis is greater in stronger lenses, as is also the effect of decentration. In bifocal glasses, therefore, in which there is both a stronger and a weaker lens, the former must dominate the position of the spectacles. Convex bifocals in which the "near" element is the stronger should, therefore, approach the "near" spectacles in position, while concave bifocals are placed more nearly like a "distant" glass, as the "distant" element is here the stronger.

A *spectacle frame* is a kind of tripod, its points of support being the top of each ear and the bridge of the nose. It is not possible to make an indifferently selected point on the bridge of the nose serve as the support of spectacles. Nearly always it will be found that there is one particular point at which they tend to rest. In adapting spectacles to any given face, therefore, the problem is to bring the optical centers to the position previously determined that they should occupy with reference to the eyes, while at the same time their support is placed at this best adapted point on the crest of the nose. The spectacle bridge known as the "saddle" bridge is the only one which allows of unlimited variation in the relation of these two points.

In fitting a frame to the face the curved portion of the bridge between *a* and *b*, Fig. 167, should be adapted to the bones of the nose at the point at

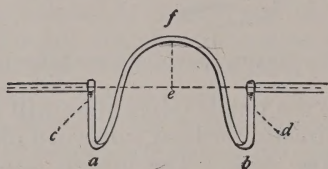


FIG. 167.—Saddle bridge.

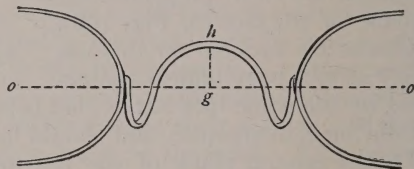


FIG. 168.—Saddle bridge.

which it is supported. Having once received the proper shape, this portion of the bridge should not be altered, as its only function is to furnish a firm, equally pressing support for the "arms" *c* and *d*, by means of which the centers of the glasses may be carried higher or lower on the face or the distance between them varied. These variations are accomplished by alterations in the angles of the wire at *a* and *b*. The length of the arms *c* and *d* governs the distance of the glasses from the eyes.

In prescribing or recording the measurements of a spectacle frame it is sufficient to give the distance between the centers of the glasses, with the height, depth, and width of the bridge. The height is the distance of *h*, Fig. 168 (the top of the bridge) above the line *o o*, joining the centers of the glasses; hence the distance from *h* to *g*. The depth is the distance between the top of the bridge (*f*, Fig. 167) and the point *e* on the plane in which the glasses lie. This distance may be a negative one—that is, *f* may be back of *e*. In the former instance the measurement is recorded as *out*, in the latter instance as *in*. The width of the base of the bridge is the distance between *a* and *b*. The measurements of a spectacle front may, therefore, be recorded in a single line, for example :

60 mm. $\times$ 5 mm. *up* $\times$ 3mm. *out* $\times$ 20 mm. *base*.

The direction in which the front of a spectacle faces depends on the angle which it forms with the side pieces or temples. If these latter are inclined

toward the bottom of the frame, the glasses when in use will face downward. It should be remembered that hook temples are simply hooks. They cannot, with comfort, be made to exert the force of a spring or a clamp upon the skin. They should touch the skin throughout the greatest possible portion of their extent, so as to distribute the weight they carry, and should not be allowed to press unequally owing to inequalities of the surface. Their proper form is a straight line from the hinge of the frame to the top of the ear, where a sharp curve joins that portion which is accurately fitted to the back of the ear, with which it is in contact.

In eye-glasses (pince-nez) the same adaptability to differently proportioned faces is found in the "offset guard," which in spectacles is attained by means of the "saddle bridge." The nose-pieces of these guards should be accurately moulded in every case to the sides of the nose at the point where they obtain the best bearing surface. Fixed points of support for the lenses are thus obtained. The height of the lenses before the eyes will now depend on the point of attachment of the "arm" of the guard to the nose-pieces. In Fig. 169, for

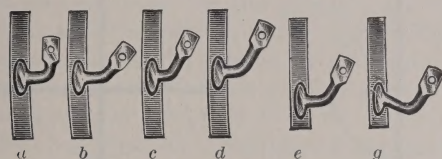


FIG. 169.—Guards of eye-glasses.

example, the guard marked *b* will carry the lenses higher than the one marked *e*. The direction in which the lenses face is controlled by the size of the angle in the arm of the guard. Thus, in the figure, at *a* the arm has a right angle and will render the plane of the lenses nearly vertical; that is, the latter will face directly forward, while at *b* the angle is greater than a right angle, and the glasses will face more downward.

The distance of the glasses from the eyes depends upon the length of this arm of the guard. The longer it is, the farther from the eyes the glasses will be held; *d* and *g*, in the figure, have longer arms than *a* or *b*. Variations in the distance between the centers of the lenses may to a limited extent be procured by an arm which is bent so that its free end does not lie in the same plane as the nose-piece. If greater latitude is required it must be procured by variation in the transverse diameter of the lens used, or by alteration of the length of the "stud" which connects the lens with the guard.

Methods of Testing Lenses.—To ensure accuracy and comfort, spectacles, before being worn, should invariably be critically examined as to the strength of the lenses and the fit of the frame.

The most convenient method of determining the strength of lenses is the well-known one of neutralization by means of the test-case lenses of known strength. In practising this manœuver the lens is held about a foot before the eye and an object several yards away is sighted. On moving the lens slowly across the line of sight the object seen through it appears to move also. In the case of convex lenses this apparent movement is in a direction contrary to the motion imparted to the lens, or, in the language of the refraction room, is "against it." With concave lenses the apparent movement of the object is in the same direction as the movement of the lens, or "with it." If a convex and a concave lens of equal strength are held together, all this apparent movement ceases; they "neutralize" each other. The surgeon is, therefore, able

to quickly discover the strength of an unknown *spherical* lens by trying it with lenses of the opposite sign until that one is found which causes all movement of the object to cease. The strength of this lens is the same as that of the unknown one.

A *cylindrical lens* is recognized by the fact that that portion of a vertical line seen through it assumes an oblique position when the lens is rotated about its optic axis (*a*, Fig. 170). If the rotation of the lens is continued, the motion of the displaced portion of the line is reversed and its continuity is restored, as at *b*. This appearance is, therefore, presented in two positions of the cylindrical lens. In one position the vertical line marks the axis of the cylinder; in the other the line is at a right angle to the axis. To locate the axis an object presenting crossed lines, as at *c*, Fig. 171, is selected; the lens is so held that each line appears unbroken and is first moved horizontally, then vertically. The line across which motion is apparent marks the axis of the cylinder. The cylindrical lens of the opposite sign which neutralizes this

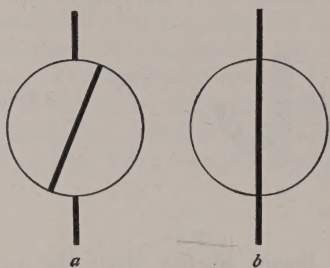


FIG. 170.—Method of testing cylindrical lenses.

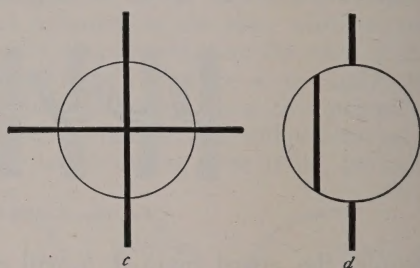


FIG. 171.—Method of testing sphero-cylindrical and prismatic lenses.

motion discloses the strength of the cylinder under examination. Care must be taken that the axes of the two coincide.

In a *sphero-cylindrical lens* the cylindrical element is recognized by its causing on rotation an apparent obliquity of a portion of a vertical line, just as did the simple cylinder. On viewing the crossed lines, *c*, however, and moving the lens first horizontally, then vertically, apparent motion of the object is imparted in both directions, but in one it is more rapid than in the other. In neutralizing, the least rapid movement may be first obliterated by means of a spherical lens. This gives the strength of the sphere in the combination. Holding these two together, one proceeds to neutralize the cylindrical element by means of a cylinder of opposite sign, precisely as though no sphere were present.

On rotating a *prismatic lens* about one's line of sight an apparent displacement of a vertical line takes place, as at *d*, Fig. 171. When the line is continuous it marks the base-apex line of the prism. At right angles to this is the meridian of maximum displacement. The prism being held at one meter's distance from the object, each centimeter of apparent displacement of the line shows one centrad of strength in the prism.

The *optical center* of a lens is located by using crossed lines, as at *c*, Fig. 171, except that for this purpose the lens is held within about a foot and the lines should be fine. When each of the lines is continuous their crossing point marks the optical center.

The distance between centers being found correct and a final inspection disclosing no flaws or scratches in the glass, no bends of the frame, or want of symmetry between its two sides, the spectacles are ready for the wearer.

DISEASES OF THE EYELIDS.

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Congenital Anomalies.—Partial or complete absence of the eyelids (*ablepharia*) is occasionally met with as a congenital defect. It may occur in one or both eyes.

Lagophthalmos is a defect in which the eyelids are wanting and the orbit is divested of any covering for the globe. An abnormal shortness of the lids, which prevents their fully covering the eyeball, has been similarly, and perhaps more correctly, so designated by many authors.

Cryptophthalmos is a condition in which the eyeball is completely concealed by the skin, which is stretched over the orbital cavity. Sometimes the eyeball is absent. Under the latter circumstances, however, the name is not an accurate one.

Cleft-eyelid (*coloboma palpebræ*) is a congenital defect in which there is a fissure of the lid, usually triangular, with the base toward the ciliary margin. The fissure may exist in either the upper or lower lid, the former being the usual seat. It has also been reported in the upper and lower lids on each side. The cleft involves the entire thickness of the eyelid and is rounded off at its margins. It occurs oftener with cases of hare-lip than with anomalies of the eyeball itself.

Symblepharon is a condition of union, either partial or complete, between the eyeball and the lids.

Another unusual congenital anomaly is a union between the margins of the lid-borders (*ankyloblepharon*). This attachment may be thread-like or involve a considerable intermarginal surface. The external angles of the lids may be adherent, producing the defect known as *blepharophimosis*, resulting in a shortening of the palpebral opening.

Ectropion is an eversion of the edges of the eyelids, frequently accompanied by enlargement of the eyeball.

Entropion is an inversion of the edges of the lids, and is usually associated with the incurving of the lashes—a condition known as *distichiasis*.

Epicanthus is an unusual congenital anomaly caused by a fold of skin which stretches across the inner palpebral space connecting the eyebrow with the bridge of the nose, the fold thus covering all the structures located at the inner canthus. It is generally bilateral, and gives rise to, or is associated with, a flattening of the bridge of the nose. Slight degrees of it may exist in children at birth, and with the development of the nasal bones this deformity gradually passes away.

Associated with epicanthus may be *microphthalmos* (sometimes only apparent on account of the diminished palpebral opening), strabismus, drooping of the upper lid, and anomalies of the lachrymal passages.

Epicanthus may be remedied by an operation in which the redundant

skin is removed from the bridge of the nose and the edges of the wound brought together with sutures.

Congenital ptosis is a drooping of the upper lid over the eyeball. It may be on one side or bilateral, and never amounts to complete closure of the lids. In this condition there is inability to raise the eyelid except by wrinkling the forehead through the action of the occipito-frontalis muscle. The anomaly is not infrequently associated with other malformations, as epicanthus, paralysis of the eye-muscles, etc. It may be corrected by operative procedures, described on page 557.

Erythema of the lids is a form of hyperemia of the skin, usually due to external irritation, such as burns, traumatism, and poisoning, or it may be indicative of some systemic disturbance. It is often well marked in inflammatory conditions of the eye.

Treatment will depend largely upon the cause, the erythema often disappearing with the cure of the primary lesion. Locally, soothing lotions, lead-water or extract of hamamelis, will be all that is required.

Erysipelas is rarely, if ever, a primary affection of the lids. It usually develops from a similar lesion of the face. The danger in this disease is that it may involve the deeper tissues of the orbit, affecting the retina or the optic nerve, and thus eventuate in blindness. In severe cases it may produce sloughing of the eyelids, with consequent deformity. The disease is characterized by great swelling, increased tension of the lids, smooth and brawny skin, deep redness, and the formation of vesicles or abscesses.

The treatment, both local and general, must be such as is usually adopted for erysipelas in other portions of the body.

Abscess of the lid (*phlegmon*) is characterized by an acute swelling of the eyelid, somewhat localized, indurated in the central portion, accompanied by much redness of the skin, heat, throbbing pain, malaise, and fever. The swelling is frequently very marked, the skin toward the height of the inflammatory stage in the severer cases often presenting a brawny appearance. Abscesses result from external injuries, from disease of the orbital walls, or they may arise from infectious causes or occur during illness—*e. g.* influenza. The tendency for the abscess to “point” is quite characteristic. Abscesses occasionally lead to extensive sloughing of the lid-tissues, and when they are not early opened they may result in lagophthalmos, ectropion, etc.

Treatment.—In the early stage ice-packs may sometimes abort the development of the abscess. Should the inflammation continue to increase, recourse should be had to hot packs and poultices to hasten the “pointing.” As soon as there is evidence of pus a free opening should be made into the center of the induration and deep enough to give vent to the pus. In making the incision care should be exercised that the fibers of the orbicularis are not cut across. The abscess-cavity may be washed out with peroxid of hydrogen or bichlorid solution, 1 to 2000, until recovery takes place.

Furuncles and **carbuncles** are rare. With them develops a “core” or central slough. Otherwise they present the same symptoms as an abscess and require similar treatment.

Anthrax pustule (*malignant pustule*) is a specific, infectious disease, due to inoculation by the poison of anthrax (*bacillus anthracis*), and is generally transferred to man from animals affected with the disease. Usually it occurs in persons working among animals, as hostlers, tanners, farriers, butchers, shepherds, etc. The disease is characterized by marked edema, redness, heat, pain, localized hardness or induration, the last indicating the point of infection. In malignant pustule, as in erysipelas, there may be very exten-

sive sloughing of the eyelid, producing at times a condition of lagophthalmos. After sloughing of the lids the ciliary margins alone may remain intact on account of the rich vascular supply. There is usually marked general depression, with fever. By absorption of the anthrax poison into the deeper tissues orbital cellulitis, or even meningitis, may ensue with fatal results.

Treatment.—This must be governed by general surgical principles. As soon as there is any evidence of pus the swelling should be freely opened, with one or more deep incisions, in order to prevent infiltration and possible involvement of the deeper structures of the orbit. The incision, followed by hot poultices or by compresses of absorbent cotton or gauze, wrung out of hot bichlorid-of-mercury solution, 1 to 2000 or 1 to 5000, will be very efficient. The administration of iron and quinin, tonics, stimulants, and good diet is of decided value.

In cases of extensive sloughing of the skin of the lids marked lagophthalmos and ectropion can be prevented by fastening the remaining marginal portion of the lid to its fellow by two or three stitches. The granular surface may then be treated with repeated skin-grafts applied according to the Thiersch-method. If this method cannot be followed, then the proper plastic operative procedures for these deformities must be undertaken, as indicated on page 555.

Ulcers of the lids may be due to contusions, burns, and various injuries, as well as to lupus, scrofula, syphilis, and herpes. The symptoms will vary with the cause; likewise the treatment.

Hordeolum (Stye).—According to the location, hordeolum may be hordeolum externum or hordeolum internum. *Hordeolum externum* is an acute inflammation of one or more of the glands of the hair-follicles. *Hordeolum internum* is an acute inflammation of the Meibomian glands. In other words, hordeolum or stye is a circumscribed inflammatory process, and is due to infection of the sebaceous glands or connective tissues of the lid, usually associated with the staphylococcus pyogenes aureus or albus.

Symptoms.—These are rapid edema of the lids, redness and tenderness coming on after a short time—a day or two—often quite severe pain, and sometimes fever and general disturbance. A hard lump or point of induration is felt at the seat of inflammation. Within a few days the color of the tissue over the stye changes from a red to a yellow hue, and the abscess “points.” If allowed to take its course, the abscess-sac ruptures, the pus escapes, and the symptoms rapidly abate.

In hordeolum internum “pointing” of the abscess takes place on the inside of the lid through the palpebral conjunctiva; in hordeolum externum, near the margin of the lid through the skin. The latter variety is much the more common.

Styes usually occur in persons subject to blepharitis, the chronic inflammation of the latter affection affording good soil for acute infectious inflammation of the solitary glands. The infectious character is well indicated by the fact that persons are very liable to successive attacks of styes, which occur, in many cases, at frequent intervals over a period of months. Young persons are generally the subjects of this disease, especially if they are scrofulous, anemic, or poorly nourished.

These two varieties of hordeolum present essentially the same clinical picture. With both there is inflammation of the sebaceous glands, and they are analogous to acne in the skin. The marked swelling of the former, as distinguished from the latter, is due to the anatomical character of the tissues in which the inflammation takes place.

Treatment.—In the early stage an attempt may be made to abort the development of a styne by the application of cold or very hot packs, or by touching the mouth of the gland involved with the sharpened point of a stick of nitrate of silver. If unsuccessful in this, “pointing” of the abscess should be encouraged by warm fomentations or properly applied poultices. Early opening of the styne is important. As soon as there is an indication of softening in the center of the induration a free incision should be made into the tumor in order to evacuate the contents and to prevent the extension of the necrotic process. Care should be taken that the incision is made parallel to the fibers of the orbicularis muscle, so that no deformity may remain. Subsidence of the symptoms is rapid after evacuation of the contents of the abscess. Between the attacks treatment should be directed toward improving the general health and alleviating the inflammation of the lid-margins; refractive errors, which may cause styne, should be corrected. Sulphid of calcium has some repute.

Exanthematous Eruptions of the Lids.—Ulcer of the lids, due to variola or small-pox, is of not infrequent occurrence. The parts attacked are the hair-follicles and sudorific follicles and glands. The results of severe attacks are pitting, cicatricial contraction of the lids, with ectropion and loss of the eyelashes, which, when permanent, produces the condition called *madarosis*.

Treatment is directed toward limiting as much as possible the ulcerative process. Protecting the pustules by dusting with a dry powder, such as starch and zinc oxid, in equal parts, or touching the ulcerated portion with a sharpened stick of nitrate of silver, has been advantageously employed.

Vaccine Blepharitis (*Vaccine Ophthalmia*, *Vaccinia of the Eyelids*).—This occasionally occurs from infection from a vaccination ulcer. It usually affects the borders of the lids, and is characterized by the rapid formation of an ulcer of the lid-margin, accompanied by much redness, swelling of the lids and of the preauricular and submaxillary glands, together with general fever, malaise, etc. In the early stage the vesicles appear with pitted center, but later the pustules are quite characteristic. In the last stages of the ulceration they resemble syphilitic ulcers, and must be differentiated from these by the history and progress of the case. Associated with the disease of the lid, marked conjunctivitis occurs, often simulating a diphtheritic membrane.

Treatment is directed toward allaying the early inflammatory symptoms, and later touching the ulcers with a 2 or 3 per cent. solution of silver nitrate. Aseptic washes to keep the eye clean should also be used.

Eczema appears either on the eyelids alone or is associated with general eczema of the face. It occurs also from the irritative secretions in chronic conjunctivitis, or in children as the result of rubbing the secretions from the eye upon the lids. It is most frequent in scrofulous or badly nourished children. Eczema is caused in adults by epiphora, ectropion, etc., the tears running over the cheeks excoriating the surface. In these cases the lesions are usually found on the lower lid.

Treatment must be directed primarily to the cause. Locally, zinc ointment or Hebra's diachylon ointment, spread on lint or muslin and applied constantly, is satisfactory. Painting the skin with a 2 to 10 per cent. solution of nitrate of silver has been found to be very serviceable; only the latter in strong solution blackens the skin on exposure to light. Its action, however, in moist or ulcerative eczema, is very effective.

Herpes zoster ophthalmicus is the term applied to that variety of

herpes zoster which attacks the skin of the eyelids and other areas supplied by the first division of the trigeminus nerve. The disease is characterized by the formation of vesicles over the terminal portion of the nerve. The attack is preceded by severe neuralgic pain over this area, succeeded by the formation of vesicles over the forehead, the eyelids, the nose, cheek, and the upper lip, the disposition of the vesicles depending upon whether the first or second division of the trigeminus is affected. The third division is rarely affected. The vesicles first contain a clear, limpid fluid, but rapidly become cloudy and purulent, and finally dry into crusts. On removal of the latter, deep ulcers are found. After healing, permanent scars remain, which, by their peculiar grouping, indicate the nature of the attack. Not infrequently the cornea is affected, which greatly complicates the case. These ulcers of the cornea may result in permanent opacities. Iritis and cyclitis are not uncommon, especially if the nasal branch is affected; indeed, there may be a destructive inflammation of the whole eye (ophthalmitis). Palsy of the ocular muscles and atrophy of the optic nerve may follow herpes.

The cause of herpes zoster is obscure, but it is an inflammatory affection of the trigeminus. Persistent neuralgia may remain after an attack of herpes.

Treatment.—This is symptomatic. The vesicles should not be opened, but these should be dusted over with a drying powder (rice starch) and the ulcers allowed to heal beneath the crusts. Removal of the latter is productive of much pain. Internally morphin, quinin, and iron, according to indications, must be given. Keratitis and iritis require the usual measures elsewhere described.

Blepharitis (*Blepharitis marginalis*, *Blepharitis ciliaris*, *Blepharo-adenitis*, *Blepharitis ulcerosa*, *Psorophthalmia*, *Lippitudo ulcerosa*, *Tinea tarsi*, *Sycosis tarsi*).—On account of the peculiar anatomical structure of the margin of the eyelid this region is subject to a variety of diseases, with somewhat characteristic symptoms, forming a group by themselves. Rich in vascular and glandular structures, the edges of the lids are the seat of marked inflammatory disturbances, the more especially as they are greatly exposed to external irritation. Therefore disorders of the margins of the lids are among the most common of all diseases of the eye. In intensity of inflammation there are all degrees, ranging from a mere red fringe of the lids to a disorganization of their borders.

Two principal varieties of marginal blepharitis have been described, according to the symptoms—(1) squamous or simple blepharitis, and (2) ulcerated blepharitis.

(1) **Simple Blepharitis** (*Blepharitis squamosa*).—In this variety the margins of the lids are bordered with a red fringe, fine bran-like scales appearing at the roots of the cilia and between them, which drop off if the eyes are rubbed. There is also a tendency for the cilia to fall out if disturbed; they grow again perfectly. When the scales are removed the skin beneath is found to be hyperemic, but not moist or ulcerated.

In another variety instead of the scales there is a wax-like secretion which adheres to the lashes, gluing them together, but on its removal there is no evidence of ulceration beneath, the tissues appearing simply red and hyperemic.

(2) **Ulcerated Blepharitis.**—In this variety there are hyperemia, redness, shedding of lashes, and crusts. When the crusts are removed by washing an ulcerative process is evident beneath them. Many yellowish-white points appear, from the center of each of which protrudes a cilium. Upon

pulling out the lash there is often found adhering to the root a small rounded drop of pus. Still deeper is found a small ulcerated base extending into the hair-follicle. The cilia are readily removed on the slightest traction.

As the disease progresses the hair-follicles are successively involved in the ulcerative process, until, not infrequently, the entire series of cilia is destroyed, leaving cicatrices with their attendant and consequent deformity. When the cilium has fallen out a new one takes its place, of a different color, more or less stunted in its growth, and in a malposition the result of cicatricial contraction of the ulcerated hair-follicles. The lashes thus become more and more stunted and misplaced or entirely destroyed.

By the cicatricial contraction the lashes may be turned backward so as to touch the eyeball, giving rise to a condition of *trichiasis*, or the entire line of lashes may be destroyed, leaving the lid bald—*madarosis*. Another result of the ulcerative process may be the gradual eversion of the lower eyelid, due to the cicatricial contraction, which pulls the conjunctiva forward upon the lid-border, the lid itself falling away from the eyeball and permitting the tears to run over, in turn increasing the irritation (*lippitudo*, or “blear-eye”). The final result is an ectropion. Hypertrophy of the body of the lid not infrequently ensues, due to the long-continued inflammation, and produces drooping of the upper lid (*hypertrophic blepharitis*). It may be seen, therefore, that blepharitis ulcerosa is a much more serious condition than blepharitis squamosa.

The patient suffers little inconvenience as the result of the disease in the milder forms, and consults a physician more on account of the disfigurement than from any great annoyance. In the more pronounced forms the sensitiveness to light, the irritation, the sticking of the lids in the morning, etc. are real discomforts. Patients are unable to use the eyes for close work with comfort, and when the lashes are greatly displaced, with the resulting corneal irritation, they become almost helpless.

Etiology.—The causes of blepharitis are twofold—viz. local and general. The *local causes* are external irritations due to vitiated air, smoke, injuries, and chronic conjunctivitis, especially if associated with excessive lachrymation, inflammation of the lachrymo-nasal passages, and disease of the rhinopharynx. Abnormal shortness of the lids may excite the affection (Fuchs). Among the *general causes* are the exanthemata, scrofula, anemia, tuberculosis, syphilis, or malnutrition from any cause.

Stubborn varieties may depend upon eczema, eczema seborrhœicum, and seborrhea, and acne of the surrounding facial areas. Staphylococci are found in the pustules, and occasionally the *trichophyton* fungus (*b. trichophytica*). The *demodex folliculorum* has also been seen in the lid-margin. Refractive errors unquestionably play an important rôle in the causation of marginal blepharitis, as well as in other irritative and inflammatory lid-diseases; but they have not yet been accorded their due weight as causative factors in these affections. Correction of these errors by proper glasses will alone very often relieve a patient from troublesome blepharitis, which other methods seem powerless to effect.

Pathology.—In blepharitis the inflammatory process involves chiefly the cilia and glands. In squamous blepharitis scales are produced on the lid-margins and the cilia fall out. These grow thinner and shorter and less pigmented, and, as the epidermis is cast off, they entirely fail to grow.

In blepharitis ulcerosa the epithelium and often the papillæ are destroyed at the seat of ulceration, and if the ulcerative process extends deeply into the

tissues of the hair-follicles, the cilia are permanently destroyed and cicatricial contractions take place.

Prognosis.—Blepharitis is essentially a chronic disease. It may last for years and not infrequently for a lifetime. In young persons it may disappear spontaneously as they grow older, while in other cases it persists in spite of all treatment. It is essential that treatment should be vigorous to prevent permanent lesions.

Treatment.—The treatment must have reference to both general and local conditions, as well as to the causes. Faulty states of the general health should be corrected by appropriate means. Excessive use of the eyes should be prohibited, refractive errors should be examined, and proper glasses prescribed. Chronic conjunctivitis, so generally present in these cases, should be relieved, and any obstruction to the free discharge of the tears through the proper channel should be removed.

For the milder forms of blepharitis the non-irritating ointments give the most satisfactory results. After carefully removing the scales and crusts with warm water by gently washing them off, an ointment should be well rubbed into the roots of the lashes and along the margin of the lids, usually night and morning. For this purpose a 1 per cent. ointment of white precipitate, as being especially mild, has been much used. The yellow and red oxids of mercury are also favorite prescriptions in the proportion of one-half to two grains to the dram of vaselin or simple cerate. A 5 per cent. solution of chloral hydrate, alternating with a salve of pyrogallol (1 : 8) and a 2 to 3 per cent. sulphur ointment, have been well recommended.

In the severer cases associated with deposits of hard and strongly adherent crusts, which glue the lashes together, the use of a solution of five grains of carbonate of sodium to the ounce of water is most effective in removing them. It is important not to irritate the bases of the ulcers too much by violent means of removing the crusts. A pledget of absorbent cotton, moistened with the above solution, enables the patient or surgeon to remove the crusts effectually and without force. After the margins of the lids and cilia have been cleared of crusts the various ointments can be applied thoroughly to the diseased structures. In case of ulceration touching the ulcers with a five- to twenty-grain solution of nitrate of silver, or with a sharpened point of a silver-nitrate stick, acts most favorably. Where abscesses occur the cilia should be epilated with proper forceps, in order to give the remedies an opportunity of acting upon the diseased structures. No hesitation need be exercised about removing the cilia, for new hairs will replace those removed, even if they are repeatedly pulled out. When the disease has resulted in extensive cicatricial disturbances, as trichiasis, etc., proper operative measures alone are to be recommended. For the condition of madarosis no treatment avails.

Phthiriasis (*blepharitis pediculosa*) is an affection resembling blepharitis, and is associated with it. The ciliary margins present a dark appearance, which is due to the presence of the nits of the pediculus pubis. Close examination with a magnifying-glass of the borders of the lid will reveal the bases of the cilia full of the black eggs of the lice, and generally many individual lice clinging to the lashes. Rubbing mercurial ointment into the margins of the lids destroys the lice and their eggs.

Syphilis of the eyelids is a somewhat rare affection. However, not only is the primary ulcer met with in this situation, but also secondary and tertiary lesions. Both soft and indurated chancres occur on the skin of the lids. The former is an ulcer with a ragged edge and with a tendency to

spread. It appears without history of injury or other cause. The hard, indurated base of the ulcer in the other case is sufficiently indicative of its nature, and in due time secondary manifestations of the disease are likely to appear.

Not infrequently the lids, along with other portions of the skin, are the seat of secondary eruptions. During the third stage, occasionally, ulcers and gummata appear in the lids, the latter often presenting a striking similarity to chalazia. These sometimes develop rapidly and undergo extensive ulcerative changes, producing ectropion, lagophthalmos, etc.

Treatment must include the proper constitutional remedies, while the extension of the ulcerative process must be combated by the use of the cautery (nitrate of silver) and proper washes, or with compresses moistened with bichlorid-of-mercury solution.

Tumors and Hypertrophies.—Many benign growths occur in the eyelids, important on account of the disfigurement which they produce. Among these are *papillomata*, or *warts*, which grow on the lids and their borders. Occasionally, from irritation, these growths may assume an epitheliomatous type and prove serious. Their early removal, with cauterization of their bases, should be practised.

Angioma (*nevus*) occurs on the lids or their margins as a congenital growth. A nevus appears as a bright-red spot, not elevated, and usually is located near the margin of the lid. Its tendency is to increase in area somewhat rapidly.

The *cavernous* variety is usually elevated, sometimes gives a pulsatile sensation, and consists of greatly enlarged vessels. It disappears under pressure and becomes much enlarged when the patient stoops over. Sometimes there may be a *bruit* present if the orbit as well as the lids is involved or if the dilatation of the vessels is extreme. The conjunctiva may also participate in the diseased process. A *phlebolith* in a varix of the conjunctival veins has been reported by Swan M. Burnett.

Small nevi may be excised or cauterized with nitric acid or with the electro-cautery by means of the platinum point. *Electrolysis* may likewise be employed with advantage. In the larger varieties the growth may be cauterized at numerous points at a little distance from one another, as the cicatricial contraction of the scars will cut off the vascular supply between. As little scar as possible should be aimed at, and frequent sittings may be advisable.

Rare forms of benign growths are *fibroma*, *adenoma*, *papilloma*, *enchondroma*, *neuroma*, and *lipoma*. The last-named growth may produce a form of ptosis—the so-called *ptosis lipomatosus*. All of these growths should be removed if they produce any disturbing effects, and this is, as a rule, not difficult of accomplishment.

Cutaneous horns sometimes attain a considerable size. They arise from the skin of the lids, often near the margin, and sometimes involve a large proportion of the lid-area. The excrescence is slow in its development and attains a horn-like hardness, especially toward its extremity. The growth should be cut off and a plastic operation replace the lost cutaneous tissue.

Xanthelasma (*xanthoma*, *vitiligoidea*) occurs in the form of rounded spots of various sizes on the surface of the skin of the eyelids. The patches are often situated on the eyelids near the inner angle, vary in size, and show a tendency to increase in numbers. They have a peculiar dark-yellow color, which is their prominent feature. They give rise to no discomfort. They occur mostly in women of advanced years.

The yellow or brownish-yellow patches may lie either on the surface of the skin (*xanthelasma planum*) or rise above it (*xanthelasma tuberosum*). These new growths of tissue are found to contain cells with granules or globules of oil. Brown or yellow molecules of pigment lie singly or in clusters in the cells and walls of the lymphatic vessels. Ablation may be practised on account of the disfigurement they produce.

Chalazion (*Meibomian cyst*, *tarsal tumor*, *cystic tumor*, *tarsal cyst*) occurs as a round tumor of variable size, giving the feeling of a shot beneath the finger. The skin over it is freely movable, but the growth has a firm attachment to the tarsus beneath.

Etiology.—The cause of chalazion is not well understood. Generally it occurs in persons subject to inflammatory disturbances of the lid-margins, frequently successive glands being attacked, one after another, until most of the Meibomian glands of one or more lids have been involved. Refractive errors seem to be an important element in many bad cases of chalazion, especially of the recurring type.

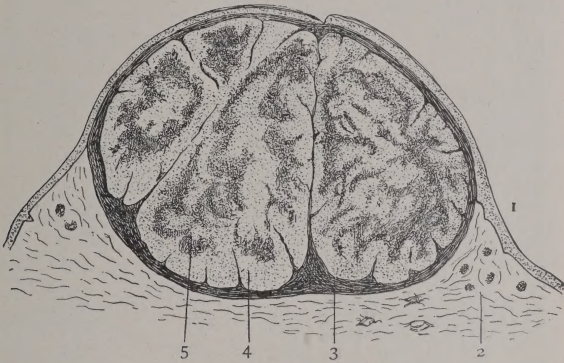


FIG. 172.—Vertical section of chalazion (Meibomian cyst); $\times 10$, glycerin: 1, stratified epithelium continued over the surface; 2, connective tissue outside tumor; 3, capsule of fibrous tissue from which septa pass inward, dividing the cyst into lobules; 4, epithelial cells inside capsule; 5, fatty material occupying center of lobules, the outer layers being more opaque (Pollock).

Pathology.—Chalazion may be solitary or several chalazia may occur in the lid, and the lower and upper lids of both eyes may be the seat of the growths. They originate in the Meibomian glands, and develop from an obstructive inflammation of the duct of these glands, which prevents the excretion of the sebaceous material. This accumulation aids in the development of an inflammatory action involving the gland and its surrounding tissue. The result is a tumor of considerable size, the contents of which, undergoing a fatty degeneration, become soft, and fill the sac with a gelatinous mass of granulation tissue containing giant-cells or with pus (Fig. 172). The process is very similar to the formation of an atheroma, except that the inflammatory changes are more marked. There is no true cyst-wall. If allowed to take its course, the chalazion develops outward, toward the skin (*external chalazion*), or involves the conjunctiva (*internal chalazion*). It frequently perforates the latter, extensive granulations springing up on the under surface of the lid, often resembling a neoplasm. Usually a catarrhal conjunctivitis, which infects the Meibomian glands, precedes the chalazion.

Symptoms.—These vary somewhat in the *acute* and *chronic* varieties. In the former the tumor may develop rapidly, with indications of much inflammation and with some pain and tenderness. It resembles a sty,

except that the tumor is more circumscribed and does not "point." The chronic variety grows slowly and causes no uneasiness to the patient, except the feeling of weight in the lid which it gives (Fig. 173). Should the growth perforate the conjunctiva, there may result some conjunctival and corneal irritation, due to the rubbing of the granulations upon these membranes. An acute chalazion is liable to be confounded with a sty, the diffuse appearance and "pointing" of the latter, however, serving to distinguish it. The chronic variety has been mistaken for small malignant growths and sebaceous cysts. The firm attachment of the chalazion to the tarsus should serve to differentiate it from a cyst. Sarcomata, when small, are difficult to diagnose, and sometimes a microscopic examination becomes necessary to determine the true nature of the growth.

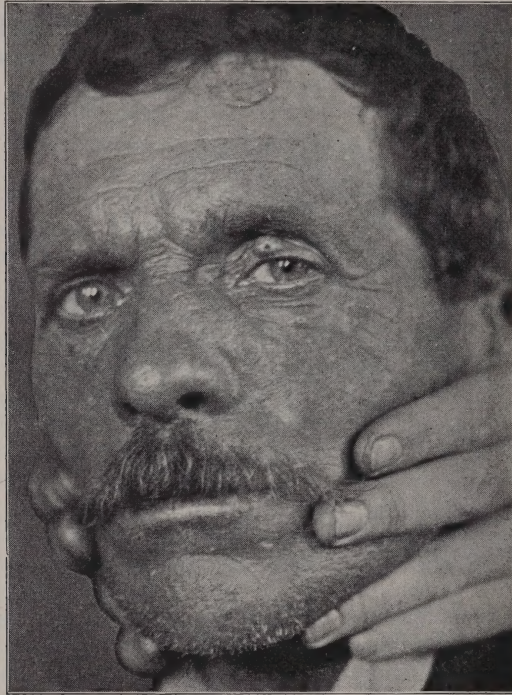


FIG. 173.—Chalazion. (From a patient in the out-patient department of the Western Reserve University, Medical Department.)

Treatment.—The only satisfactory treatment for chalazion is surgical. Some relief, perhaps, may be afforded in the acute variety by frequent hot packs, followed by the use of the yellow-oxid-of-mercury ointment. The proper surgical procedure for its removal is described on page 546.

Sarcoma, as a primary growth, develops in the connective tissue of the lids, and occurs usually in children. In the early stage of its growth the skin moves freely over the tumor, but this rapidly invades the overlying tissues, which break down and become ulcerated. Sarcoma of the eyelids, of the small spindle-celled variety, may result from traumatism. It sometimes resembles a chalazion, but careful examination is likely to show a deeper coloring, with diffuse swelling. Microscopical examination alone will sometimes determine the true nature of the trouble.

Primary sarcoma of the eyelid may arise from any of the subepithelial

tissues, and may be of the spindle-, large or small round-, or mixed-celled variety. Pigmentation of cells or cells and stroma is sometimes seen (*melanosarcoma*). W. H. Wilmer, who has described a melanotic giant-celled sarcoma, has analyzed 35 cases, and finds that 40 per cent. were spindle-celled, 43 per cent. round-celled, 17 per cent. mixed, and 11 per cent. presented myxomatous elements.

An early excision of the growth alone offers any hope of protection against a fatal outcome of the trouble. Even after thorough removal return of the growth occurs in 40 per cent. of the cases (Wilmer).

Carcinoma.—The most usual type of carcinoma of the lid is the epitheliomatous ulcer, commonly called "rodent or Jacob's ulcer." The border of the lid is the favorite starting-point for the growth, which occurs in elderly persons. It usually begins as a small pimple covered with a crust, and its

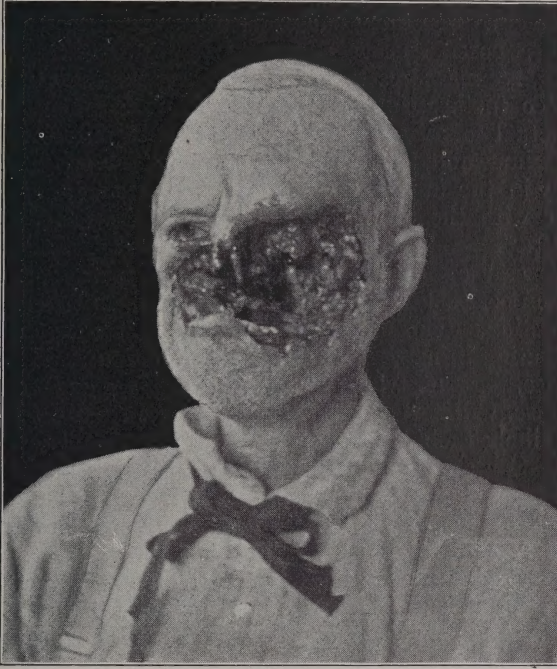


FIG. 174.—Rodent ulcer beginning in the left lower eyelid. (From a patient in Charity Hospital, Cleveland, Ohio, under the care of Dr. Dudley P. Allen.)

growth is often exceedingly slow. As time goes on it gradually develops into a flat ulcer, with indurated, ragged, and elevated edges, attended with only a slight secretion. Eventually it may involve the lids, eyeball, and adjacent structures (Fig. 174). Rodent ulcer may be mistaken for a syphilitic ulcer, but generally the age of the patient, the slow growth of the tumor, and the therapeutic test with iodid of potassium, which rapidly relieves a syphilitic ulcer, suffices to differentiate the epithelial growth from the latter affection. It is distinguished from lupus, because this disease occurs usually in young subjects, because of the greater inflammatory action of lupus, and because other portions of the body are at the same time similarly affected.

Pathology.—Ordinary epithelioma of the eyelid presents no differences from epithelioma of the skin elsewhere. From the greatly thickened epidermis irregular outgrowths penetrate into the subepithelial structures. Epithelial

cell-nests may also lie in this layer, together with "epithelial pearls." The surrounding tissue is usually very vascular and infiltrated with round and epithelial cells. The growth may originate from the epidermis or from the epithelial lining of the sebaceous or sweat-glands; rarely from Meibomian glands. At times it appears as a raised ulcer with infiltrated edges. The growth may be very slow, and cicatrization take place in the center as the ulceration progresses at the edges. If the ulcerative process is an elaborate one and extends into the deeper as well as surrounding tissues, a "rodent ulcer" results. The stroma of these epitheliomata is always more or less infiltrated with round-cells and presents the appearance of granulation-tissue.

Rare forms of cancer of the lid-structures having their point of origin in the Meibomian or in Krause's glands may be denominated *glandular carcinomata*, in contradistinction to the ordinary *epitheliomata* and *rodent ulcers*.

Treatment.—Radical measures alone give any promise of permanent relief in carcinomata. An early operation for their removal should be performed and the exposed surface covered with suitable skin-flaps. In the later stages palliative measures to aid in limiting the rapidity of the growth may be used. To further this end caustic, chloracetic acid, seraping with a curette, or the actual cautery may be employed. As milder measures aristol, chlorate of potassium, and injections of pyoktanin have been recommended. Not infrequently in the advanced cases it may be necessary to remove the eyeball, together with the orbital and periorbital tissues.

Lupus Vulgaris.—Associated with lupus of the face or nose the eyelids may become the seat of this affection. The ulcers are formed by several points of infection coalescing and producing ragged, soft edges, which exude an offensive secretion.—The disease frequently inflicts much damage to the lid-tissue, eventuating in marked cicatricial contraction and deformity. The history of the case, together with the fact that the face and nose are involved in the same disease, will serve to distinguish lupus from the *syphilitic ulcer*, for which it is likely to be mistaken.

Treatment.—Cauterization by means of caustic paste or the actual cautery gives the best results in the early stage of the disease. The ulcers may also be curetted. When the ulcers are large excision may be practised, with the proper plastic operation for covering the denuded surface of the eyelids.

Lepra.—Leprosy of the eyelids is very frequent in countries where the general disease is prevalent. Tubercular growths form in the region of the brows and cilia, producing loss of the lashes and eyebrows. Anesthetic patches of a color slightly different from the surrounding skin, with entropion and ectropion, are frequently developed.

Elephantiasis Arabum is characterized by a chronic hypertrophy of the skin and subcutaneous tissue. The lids reach enormous proportions, and from their mere weight prevent the patient from opening the eyes. The upper lids are the ones usually affected. Elephantiasis occurs congenitally or may result from an injury. According as the hypertrophy affects the lymphatics or the blood-vessels the names of *elephantiasis lymphangiectodes* and *elephantiasis telangiectodes* have been assigned. Removal of the excessive growth of tissue sufficient to enable the patient to open the eyes offers the most hope of relief.

Tarsitis is usually a chronic inflammation of the tarsus characterized by thickening of this body. *Acute tarsitis*, with sloughing of the tissues, has been described. There is often found associated with conjunctivitis and blepharitis a thickening of the tarsus, especially in scrofulous subjects. *Syphilitic tarsitis* is the most frequent variety of the disease, and in this

affection the thickening of the lids is often very marked, giving rise to much deformity. It usually occurs in the third stage of syphilis, and assumes the gummatous type of the disease; more rarely an *acute* form appears.

The **symptoms** of tarsitis are gradual thickening of the lid, without marked inflammatory disturbance, and the consequent inconvenience to the patient of the bulk of the eyelid, which may droop over the globe. If the lower lid is the seat of the disease, the weight of the lid sometimes pulls it away from the eyeball, producing an ectropion. In severe cases an atrophy of the tarsus may ensue after the subsidence of the inflammation (Fig. 175).

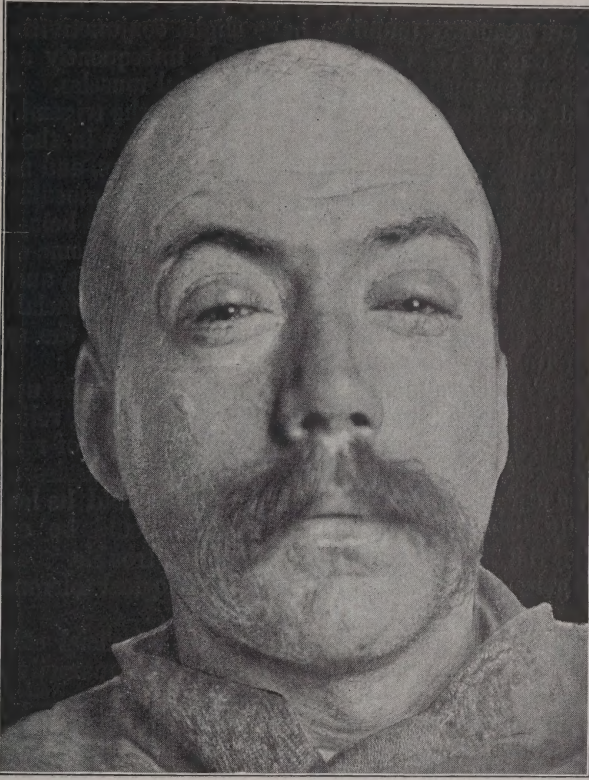


FIG. 175.—Syphilitic tarsitis. (From a patient under the care of Dr. de Schweinitz in the Philadelphia Hospital.)

Treatment.—The remedies appropriate to blepharitis should be used locally, and any constitutional disturbance corrected by proper means. In tarsitis syphilitica treatment suitable for the specific disease should be instituted. Recovery is slow, but generally perfect.

Blepharospasm is characterized by a cramp-like contraction of some or of all of the fibers of the orbicularis muscle.

A frequent condition in many persons is the contraction of a few fibers of the orbicularis muscle in either the upper or lower lid, which is very annoying. The twitching of the muscle may readily be seen by an observer. This condition is usually indicative of some local irritation of the eyes or the lids, and is of no great import.

A more serious and uncomfortable phase of the difficulty is cramp of the entire muscle, when the eyelids close tightly and violently. There are two

varieties of blepharospasm—the *clonic* and the *tonic* spasms. In the former the spasm is of momentary duration, and consists of a series of forcible uncontrollable “blinkings;” in the latter there is a violent closure of the lids, which remain tightly shut for some minutes or for days or months, and the patient is rendered practically blind by the inability to use the eyes. Blindness has occasionally resulted, manifest when the patient has become able to open the eyes, either with or without grave ophthalmoscopic changes.

Blepharospasm may be either a symptomatic condition or an essential disease. Children especially are prone to have slight more or less frequent “blinking” attacks or nictitation, especially when using their eyes in school-work. They are generally found to have slight conjunctivitis or an asthenopic condition due to refractive error. Not infrequently associated with this is a choreic or spasmodic affection of the facial muscles. Blepharospasm is essentially due to reflex irritation of the fibers of the trigeminus, and hence occurs in follicular conjunctivitis, with foreign bodies in the eye (when the spasms may be tonic), with blepharitis, refractive errors, and muscular insufficiencies. Depending upon the cause, the attacks are monocular or binocular, the latter form prevailing in all severe cases, the attacks being usually more severe on one side. In hysterical subjects the attacks come on without any known cause, the eyes close tightly, the spasm is persistent, and the patient is rendered helpless. In adults as well as in children the facial muscles may twitch as actively as the orbicularis. In elderly people the spasm is often associated with tic or with chronic conjunctivitis.

Treatment.—The treatment of blepharospasm depends upon the cause. In case of local irritation removal of the foreign body, relief of conjunctivitis, blepharitis, or other local inflammation, correction of refractive errors, and gymnastic exercise for insufficiency of the eye-muscles are the essential points to be considered. The general health should be looked into, and tonics, especially iron, quinin, and strychnin, should be exhibited, care being taken that the latter does not aggravate the trouble. Antispasmodics, as conium and gelsemium, pushed to their physiological tolerance, may be of benefit.

In many cases medication seems to have no beneficial effect. In some patients pressure on certain points seems to relieve temporarily the difficulty. The patient discovers these and learns to control, in a measure, the orbicularis spasm by pressing upon the point. This point may be situated on the forehead or in some other portion of the head. In such cases galvanism, or, in very bad cases, hypodermic injections of morphin in these regions, may be tried. Complete rest from work, with change of climate, sea-bathing, or mountain-climbing, have sometimes proved efficacious when other means have failed.

Ptoxis (*blepharoptosis*, *blepharoplegia*) is a term properly applied to a drooping of the eyelid due to paralysis of the levator palpebrarum muscle. In addition to true ptoxis there is a more or less marked degree of drooping of the lid due to its increased weight or bulk, which prevents the levator from sufficiently raising the lid to expose the eyeball. This often is the case in tarsitis, hypertrophic blepharitis, granular conjunctivitis, and tumors of various sorts occurring in the substance of the lid. But ptoxis proper is due either to paralysis of the oculo-motor nerve or to a fault in the development of the levator muscle itself.

The affection may be a *congenital* or an *acquired* one. In the congenital cases the ptoxis may be associated with other congenital malformations of the lids, eye, or orbit. In some cases of unilateral congenital ptoxis, usually on

the left side, while the eyelid cannot be raised voluntarily, it is raised when the jaw is moved during eating, or there is contraction of the levator in association with the external pterygoid. Not infrequently ptosis is the result of injury to the muscle-fibers or to the supraorbital branch of the oculo-motor (Fig. 176). Paralysis of the eye-muscles is frequently associated with ptosis, and it may be found in certain cases of hemiplegia or from lesion of the cortical center. In bilateral ptosis the peculiar pose of the head, which is thrown back to enable the patient to look under the drooping lids, is strikingly characteristic.

Treatment.—The cause must determine the proper procedure. Medicinal measures must be instituted if the palsies are of syphilitic, rheumatic, or of



FIG. 176.—Traumatic ptosis with cystic tumor of orbit. (Western Reserve University, Medical Department.)

other origin which is amenable to medicinal agents. The surgical treatment is described elsewhere (see page 557).

Lagophthalmos manifests itself by an inability of the eyelids to close, the degree of this immobility varying as the cause is a *paralytic* or a *non-paralytic* one. The non-paralytic causes are—shortening of the eyelids, which may be congenital or due to loss of tissue of the lids from burns, ulceration, gangrene, etc.; ectropion; loss of reflex sensibility in the eyeball and protrusion of the globes, so that the lids are unable to cover them, as in exophthalmic goiter, orbital tumors, etc.

The most marked cases are caused by paralysis of the orbicularis muscle, usually associated with facial paralysis. The distressing symptoms of lagophthalmos arise in connection with the cornea, which is exposed to external irritations and suffers the loss of the lubricating and protecting action of the lids. The exposed portions of the cornea and conjunctiva become chronically inflamed, and ulceration and even blindness may be the result.

Treatment should have in view, primarily, the protection of the eyeball from external irritation. Patients are likely to suffer most while asleep from inability to close the lids by voluntary action. Hence in bad cases the lids

should be closed with adhesive plaster, a compress and bandage, or by other suitable means. Relief should be directed to the cause of the affection in the paralytic variety, and the operation of tarsorrhaphy (page 547) may be required.

Symblepharon is an abnormal adhesion of the eyelid to the eyeball. It may be congenital, but is usually the result of injuries, especially burns from acids, lime, or hot metal (Fig. 177). It occurs always when the conjunctival structure is destroyed in its sulcus and when the palpebral and bulbar conjunctivæ are cauterized in approximate positions. It also results from purulent and granular conjunctivitis, pemphigus, etc. Not infrequently the lid-margins become strongly adherent to the cornea by cicatricial bands or the entire body of the lid may be adherent (Fig. 178).

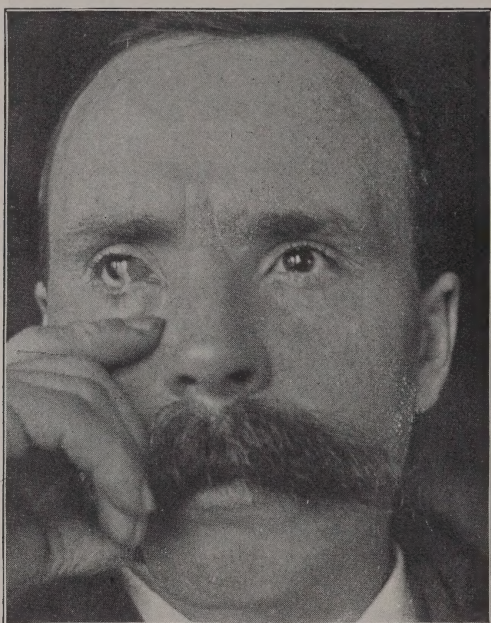


FIG. 177.—Symblepharon due to burn—hot metal. (From a patient in Western Reserve University, Medical Department.)

Ankyloblepharon has the same causes as symblepharon, and likewise may be *congenital* or *acquired*. It consists of a union between the margins of the upper and lower lids, and may be *partial* or *complete*. In the acquired variety burns are the most common cause.

Blepharophimosis is an agglutination of the eyelids at the outer angle of the eye, caused usually by chronic conjunctivitis or ulceration at the commissure. The adhesions cause shortening of the palpebral opening.

Treatment.—These conditions, generally due to a similar cause, require like treatment. In case of injury, burns, etc. care should be exercised to keep the lids well separated from each other as well as from the eyeball. In case of extensive burns of both the bulbar and palpebral conjunctivæ no method will prevent the lid and the eyeball from becoming adherent, with the formation of a more or less complete symblepharon. When the deformity has occurred suitable surgical measures should be employed for its correction (see page 548).

Trichiasis is a term used to describe that condition of the lids where the eyelashes are turned backward so as to rub against the eyeball. A single cilium or the entire row of lashes may be inverted.

The most frequent cause of trichiasis is trachoma. The entire conjunctival surface being, as a rule, involved in chronic trachoma, the resulting cicatricial contraction affects the entire border of the lid and occasionally develops more or less complete trichiasis. The more localized affection is likely to be due to burns, blepharitis, injuries, operations, etc. The result of the lashes turning in is marked irritation of the cornea, which often results in ulcers; thickening of the epithelial covering, somewhat simulating pannus; constant lachrymation; and, in long-continued cases, permanent impairment of vision.

Distichiasis is a term applied to that affection where there are double

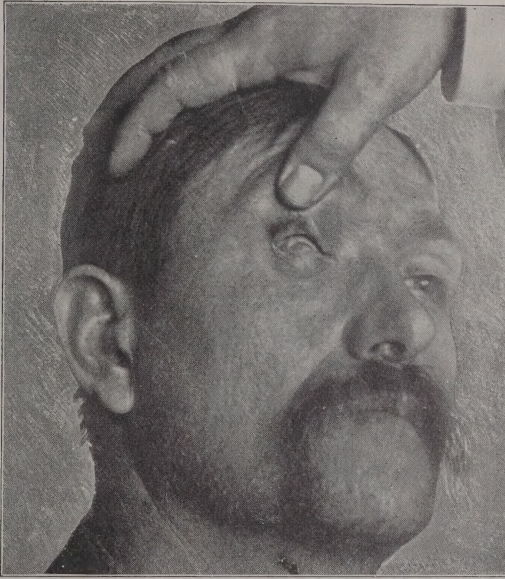


FIG. 178.—Complete symblepharon due to burn. (From a case in Western Reserve University, Medical Department.)

rows of lashes, one row being directed properly, while the other is turned backward against the eyeball. Some authors consider distichiasis simply one step in the development of trichiasis and assign the term to the congenital affection alone. The causes of the two affections are the same.

Treatment.—Should a single lash or a small number of lashes turn in, temporary relief is afforded by *epilation* of the cilia which are at fault. The lashes grow again, however, and this operation must be frequently repeated. Patients can often remove the lashes themselves with a pair of cilium forceps. For permanent relief *electrolysis* or some other operative procedure must be employed (see page 545).

Entropion is a turning inward against the eyeball of the external lid-margin. Not only the lashes but the skin of the palpebral margin is rolled back against the eye. Two varieties of this affection have been described, the *spasmodic* and the *organic*. The former results from the over-action of the orbicularis muscle due to the reflex irritation of conjunctivitis, keratitis, etc. In elderly people it not infrequently results from operations when the eye has been kept bandaged too long. The organic type results from chronic

trachoma, diphtheritic conjunctivitis, burns, injuries, etc., which lead to cicatricial contraction of the conjunctiva. The effect upon the cornea may be serious on account of the production of ulcers, opacities, etc.

Treatment.—Spasmodic entropion is generally relieved by the disappearance of the conjunctivitis, keratitis, or foreign substance which has caused it. Early removal of the bandage is necessary when the entropion occurs after cataract operations. Strips of adhesive plaster applied to the lid-margin by one extremity and by the other to the cheek, or collodion painted over the lid, or strips of gauze fixed with collodion applied in the same manner as the adhesive strips, serve a most useful purpose in case of spasmodic ectropion. The *serre-fine* has been used with advantage by fixing a fold of the skin, thus pulling the lid-margin away from the eyeball. The chronic types of entropion require careful surgical treatment. The operations are described on page 548.

Ectropion is a rolling outward of the eyelids, so that the conjunctival portion is exposed to view. This eversion may be *partial* or *complete*. It

may also be *spasmodic* or *muscular* and *chronic* or *organic*. In the former case it is due to the over-action of the peripheral fibers of the orbicularis muscle. The lower lid sometimes shows a tendency to droop, particularly in elderly people and in persons affected with facial palsy. The tears thus run over the cheeks and occasion additional irritation.

The causes of organic ectropion are those which produce a cicatricial shortening in the length of the eyelids, as chronic blepharitis, lupus, necrosis of the orbit or malar bone, abscesses, burns, and injuries (Fig. 179). The eye being more or less exposed, the cornea suffers from external irritants.

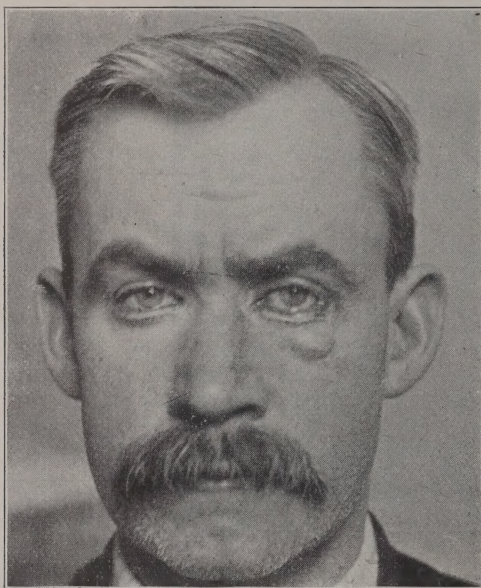


FIG. 179.—Case of ectropion. (From a patient in the Charity Hospital.)

Treatment.—Not infrequently the excessive lachrymation which occurs in ectropion may be cured by slitting up the canaliculus and passing probes through the naso-lachrymal duct. Associated inflammation of the cornea and conjunctiva should receive attention. The severer chronic forms of the affection require operative measures for their relief (see page 551).

Seborrhea is characterized by a secretion on the margin of the lids either of an oily fluid or of a sebaceous material, which dries, forming crusts or scales along the cilia. Generally, seborrhea of the face, scalp, or other portions of the body is an accompanying affection. It not infrequently occurs in young persons about the age of puberty. Conjunctivitis and marginal blepharitis are frequent concomitants.

Treatment must be directed to the improvement of the general health. Removal of the crusts and the application of mercurial or sulphur ointments, together with measures suited to conjunctivitis and blepharitis, are required.

Milium.—Milia are accumulations of sebum in closed sebaceous glands. These growths are about the size of a milletseed, from which they take their name. They present a yellowish-white appearance, and are slightly elevated above the surrounding skin, giving the feeling of a pinhead under the finger. They usually indicate improper care of the skin, and occur in persons with some disturbance of digestion, constipation, etc.

Treatment.—Hot applications, frequently repeated, together with suitable remedies for indigestion or constipation, will prove beneficial. After removal of the milium with a knife-point or needle, hot packs and mild ointments, well rubbed in, will afford relief.

Mollusum contagiosum (*mollusum sebaceum*) occurs in the lids in the form of small rounded tumors which originate from the sebaceous glands. They attain the size of a pea, have an umbilicated appearance due to the orifice of the gland on the summit of the growth, and have a wax-like color. The material from the growths is contagious. The disease not infrequently occurs among children in asylums and schools in the nature of an epidemic. The contagious nature of the disease is supposed to be due to a parasite, and the affection is allied in character to *contagious epitheliomata*. The parasite is believed by some authors to belong to the class *Coccidia*, and to inhabit the epithelial cells and cause the formation of these small prominent epithelial growths. The coccidia multiply in the cells of the epithelial projections; these are then cast off and accumulate as a mass of epithelial detritus. According to H. Muetze, the mollusum corpuscles are the product of a degeneration of the epithelial cells caused by the contagium, the nature of which is uncertain; but the corpuscles themselves are not parasites.

Treatment consists of opening each mollusum and scraping out its contents. Cauterizing the sac with nitrate of silver may also be employed.

Ephidrosis (*hyperidrosis*) is a rare affection of the lids characterized by profuse secretion from the sweat-glands. It is associated with excessive sweating of other portions of the face or body, and has been noticed in cases of unilateral facial sweating. Its cause is not understood. It may produce excoriations, especially at the angles of the eyes and in the skin-folds.

Treatment must be directed to the excoriations of the skin and to the cause if it can be discovered.

Chromidrosis (sometimes called *seborrhœa nigricans*¹) is the formation of various colored secretions on the eyelids, the oily-like fluid giving a bluish or blackish color to the affected skin. It usually occurs on the lower lid. The discoloration can readily be removed by wiping. Some authors believe that it is always an evidence of malingering, as it most frequently occurs in hysterical patients, particularly young women. In rare instances it is genuine. It may be caused by a deposit of dust upon a cutaneous surface affected with seborrhea.

Treatment should be directed toward the relief of any general disturbance of the health. The discoloration may be removed with some oily substance; lead-water and glycerin have been recommended.

Sebaceous cysts are small rounded bodies of the size of a pea or of a hazelnut which occur in the thicker portions of the skin of the eyelids, especially in the superior or external orbital portion of the lid (Fig. 180). They develop from the sebaceous follicles of the skin, and contain a sebaceous, oily-like material, and frequently fine hairs. They have well-formed

¹ For a full account of this affection see a paper by Dr. J. K. Mitchell in the *Phila. Med. Journ.*, 1898, i. 117-119.

cyst-walls, which enables the surgeon to dissect them out without great difficulty, this being the proper method of treatment.



FIG. 180.—Sebaceous tumor of the eyelid. (From a patient in the Western Reserve University, Medical Department.)

Dermoid cysts likewise occur in the same region and should be removed in like manner.

Cysticercus has been observed a few times under the skin of the eyelids, having the appearance of a sebaceous cyst, only the contents are fluid. On opening the tumor the remains of the parasite are discovered.

THE EYEBROWS.

The eyebrows may be the seat of eczema or of seborrhea, and are a favorite situation for the development of *sebaceous* and *dermoid* cysts. Occasionally these growths extend some distance into the orbit, where by pressure they may produce a depression in the underlying bone.

DISEASES OF THE LACHRYMAL APPARATUS.

By SAMUEL THEOBALD, M. D.,

OF BALTIMORE.

IN treating of diseases of the lachrymal apparatus it is convenient to consider, first, those affections which have to do with the *lachrymal gland* and its *ducts*, and, second, those of the *drainage apparatus*, including the puncta, the canaliculi, the lachrymal sac, and the nasal duct. The lachrymal gland, probably owing to its protected position and its multiple ducts, is, comparatively speaking, rarely the seat of disease, while, on the other hand, disease of the drainage apparatus, doubtless because of its intimate anatomical and pathological relationship to the nasal passages, is of very frequent occurrence.

DISEASES OF THE LACHRYMAL GLAND.

Dacryoadenitis, or inflammation of the lachrymal gland, occurs as an *acute* and as a *chronic* affection. Both varieties are rare, though it seems not improbable that acute inflammation of the gland is sometimes mistaken for cellulitis of the orbit, from which it is not always easy to differentiate it.

Etiology.—It occurs more frequently in children than in adults, and oftener in women than in men. It has been known to assume an epidemic character, and Galezowski reports having met with an unusual number of cases during an epidemic of mumps. Other causes to which it has been ascribed are traumatism, "cold," rheumatism, gout, struma, syphilis, septic absorption, and the extension of inflammation from the conjunctiva and cornea. It is usually unilateral, but not infrequently both glands are involved.

Symptoms.—*Acute dacryoadenitis* gives rise to severe pain, which may be accompanied by elevation of temperature, cerebral excitement, sleeplessness, and delirium. The lids, especially the upper lid, are greatly swollen, and there is marked chemosis of the conjunctiva. The eyeball may be displaced and its movements restricted and rendered painful through the enlargement of the gland. Palpation of the exquisitely sensitive gland is difficult because of the edema of the lids, and eversion of the lid, to permit of its inspection, is out of the question. The general appearance of the eye is not unlike that which characterizes purulent conjunctivitis (S. C. Ayres). Suppuration may supervene within a few days, the pus making its way through the integument of the lid or into the conjunctival cul-de-sac, or the inflammation may subside without the formation of pus.

In *chronic dacryoadenitis* the characteristic enlargement of the gland may be recognized by palpation, and sometimes by simple inspection. By everting the upper lid the swollen gland may be brought into view as a red, tongue-shaped, nodular mass (Hirschberg). The gland is usually sensitive to pressure, but the pain, swelling of the lids, and conjunctival chemosis are much less pronounced than in the acute variety of the disease. As in the latter, there may be marked displacement of the eyeball, usually downward and inward,

and this may give rise to diplopia. In rare instances non-suppurative dacryo-adenitis (*mumps of the lachrymal gland*, Hirschberg) is bilateral.

Treatment.—The treatment of acute dacryoadenitis, if the case is seen at the outset of the attack, should consist in leeching, the application to the lid and brow of an ointment of mercury with opium or belladonna (ext. opii vel ext. belladonnæ ʒj; ung. hydrarg. ʒj), and the administration of an energetic mercurial purgative, to be followed by liberal doses of quinin, sodium salicylate, or sodium pyrophosphate (the last-named drug in twenty-grain doses every two hours); or, instead, small and frequently repeated doses of calomel may be administered. Should these measures fail to cut short the attack, warm fomentations, containing opium or belladonna, should be employed, and as soon as the presence of pus can be detected it should be evacuated by an incision either through the integument of the lid or through the conjunctival cul-de-sac as may seem to be indicated.

In chronic inflammation of the gland the local application of mercurial or compound iodine ointment, and the administration of alteratives and tonics, are indicated. Extirpation of the gland (see page 596) may be necessary should it become so enlarged as to endanger the integrity of the eyeball.

Fistula of the Lachrymal Gland.—This troublesome variety of lachrymal fistula may be a consequence of dacryoadenitis or may be of traumatic origin. Cases of *congenital fistula* of the lachrymal gland have also been observed.

The fistulous opening is usually at some point in the upper lid, and the constant flow of tears, which prevents its closure, gives rise to much annoyance.

It is not easy to bring about a healing of the fistula, and if this is accomplished, it is at the risk of precipitating a fresh attack of inflammation of the gland. The operative procedure which has proved most effectual is that proposed by Sir William Bowman (see page 596).

Dacryops, or *cyst of the lachrymal gland*, is a rare condition due to occlusion of one or more of the efferent ducts of the gland. It has also been met with as a congenital affection.

Upon eversion of the upper lid the cyst may be brought into view as a semi-transparent, elastic swelling, consisting, perhaps, of several nodules. During a spell of crying the cyst may become markedly increased in size.

Treatment.—This consists in establishing a permanent opening between the cyst and the conjunctival sac. This may be done by removing a portion of the cyst-wall and preventing the closure of the wound by the repeated introduction of a probe, or, as suggested by von Graefe, a silk thread may be passed through the wall of the cyst, tied in a loop, and left to cut its way out.¹

Dacryoliths (*Lachrymal Calculi*).—Chalky concretions, known as *dacryoliths*, occasionally form in the lachrymal gland. As they are apt to cause mechanical irritation, their early removal (through a conjunctival incision) is indicated.

Dislocation of the Lachrymal Gland.—This affection, sometimes described as *hernia* or *prolapse of the gland*, has been met with as a spontaneous condition, and also as a consequence of injury involving the neighboring parts.

Cases of *spontaneous dislocation* of the gland have been reported by Snell, Noyes, Mauthner, and Brière. In Brière's case the luxation of the gland

¹ An interesting paper upon fistulae and cysts of the lachrymal gland, by Mr. Hulke, may be found in the *Royal London Ophthalm. Hosp. Reps.*, vol. i. p. 285.

was due to caries of the orbit, and was accompanied by ectropion of the upper lid.

Von Graefe and Rampoldi have reported cases of *traumatic dislocation* of the gland.

If possible the gland should be restored to its normal position, as was done successfully in von Graefe's and in Snell's cases, and a compress bandage should be applied and worn for a time to prevent a redislocation. If this cannot be accomplished, removal of the gland may become necessary (see page 596).

Hypertrophy of the Lachrymal Gland.—This condition occurs more frequently in children than in adults, and has been known to be of congenital origin. The enlargement of the gland may become so great as to force the eyeball from the orbit, and destroy the sight through stretching and compression of the optic nerve.

The accompanying illustration (Fig. 181) represents a striking example of a case of this character which occurred in the practice of the late Prof. Christopher Johnston of Baltimore. The hypertrophied gland, which was about the size of a hen's egg and contained numerous *dacryoliths*, was removed through an incision made parallel with the orbital margin. The eye subsequently resumed nearly its normal position, and retained vision equal at least to counting fingers.



FIG. 181.—Hypertrophy of the lachrymal gland.

If the enlargement of the gland is so great as to endanger the integrity of the eye, it should be removed without unnecessary delay (see page 596); but if it is not so great as to interfere with vision, less radical measures, such as the local application of iodine or mercury and the administration of the iodides, may be tried. The fact that the hypertrophic process may be of syphilitic origin (*syphilis of the lachrymal gland*) should not be lost sight of in considering the treatment to be adopted.

Atrophy of the Lachrymal Gland.—This has been observed in xerophthalmia (see page 296). Arlt has described a case of this character in which the gland was reduced to one-third its normal size and its efferent ducts obliterated. In paralysis of the trigeminus the functional activity of the lachrymal gland may be abolished.

Tumors of the Lachrymal Gland.—These are rare, and, not infrequently, are traceable to some previously received injury. They are usually of slow growth and occur oftenest in advanced life. As they increase in size they interfere with the movements of the eyeball, giving rise to diplopia. Later they produce exophthalmos, and eventually may not only destroy sight by the pressure which they exert upon the optic nerve—but which they rarely invade—but may cause death by the involvement of the brain.

The following varieties of tumors believed to have had their origin in the lachrymal gland have been observed: adenoma, myxoma, myxo-sarcoma,

lympho-sarcoma, spindle-cell sarcoma, epithelioma, cylindroma, chloroma, and carcinoma.

Early and complete removal of the growth is of course indicated. Whether this can be accomplished successfully without sacrifice of the eye will depend upon the size of the tumor and the extent to which it has invaded the deeper portions of the orbit. (See page 596 for description of operation for removal of lachrymal gland.)

DISEASES OF THE DRAINAGE APPARATUS.

All parts of the drainage apparatus are liable to pathological changes, and, whether these changes affect the puncta, the canaliculi, the lachrymal sac, or the nasal duct, a common symptom characterizes them all: the tears are no longer carried from the conjunctival sac to the nasal cavity, as in the normal state, but, instead, overflow the lids, giving rise to the annoying condition known as *epiphora* or *stillicidium lacrymarum*. Not only is this condition, in itself, very annoying, but it leads to chronic conjunctivitis, blepharitis, and not infrequently to eczema of the lids and cheek.

Atresia of the Lachrymal Puncta.—This condition is met with as a *congenital* and as an *acquired* anomaly.

Congenital atresia of the puncta, of which not many authentic cases have been reported, may be attended by absence of the corresponding canaliculi. The writer has encountered one case of this character, in which, however, only one punctum with its canaliculus was absent.

Complete obliteration of the puncta as an *acquired* condition seldom occurs, except as the result of destruction of neighboring tissue, such as happens, for example, from burns of the eye by lime, etc. It has also been known to follow the cicatrization of a small-pox pustule and of a chancre of the lid.

A superficial occlusion of the lower punctum, which is easily overcome, and which is chiefly due to desiccation of the parts, is often observed in blepharitis marginalis complicated by ectropion.

Treatment.—Whether the occlusion be congenital or acquired, it is, as a rule, overcome without much difficulty, provided the canaliculus is not involved. A slight depression usually indicates the site of the occluded punctum, and with a straight, moderately sharp-pointed probe, such as is represented in Fig. 182, an opening may be drilled into the canaliculus at this point and

FIG. 182.—Sharp-pointed lachrymal probe.

kept from reclosing by the occasional introduction of a somewhat larger probe. If, however, the canaliculus as well as the punctum be occluded, or if the latter be everted, the canaliculus will require to be slit up to its point of juncture with the lachrymal sac. (For description of this operation see page 596.)

As *congenital* anomalies *double puncta* and *double canaliculi* have been observed, and in connection with absence of the puncta the canaliculi have been represented by slight furrows along the lid-margin.

Malpositions of the Puncta.—In their normal position the puncta lie in contact with the eyeball. Malpositions of the upper puncta are not common, but faulty positions of the lower puncta are frequently met with.

Eversion of the puncta is present in nearly all cases of ectropion; it also occurs in inflammatory thickening of the lid-margin, in senile relaxation of the palpebral tissue, and in facial paralysis.

Inversion of the puncta is met with in entropion. Occasionally, owing to the small size or deeply-set position of the eyeball, the puncta are not in apposition with it, and epiphora results, as it does when the puncta are everted, through failure of the tears to find their way into the canaliculi.

Treatment.—The efficient remedy in all malpositions of the puncta is division of the canaliculus. It not only relieves the epiphora, but usually leads to the rapid disappearance of the conjunctivitis and blepharitis which are its common accompaniments.

Atresia of the Canaliculi may occur as a *congenital* defect in connection with absence of the puncta, as has already been mentioned; it may also be of *traumatic* origin.

Circumscribed strictures of the canaliculi, located usually near the juncture of the canaliculi and the lachrymal sac, are of frequent occurrence, especially in association with stenosis of the nasal duct.

When the canaliculi are completely obliterated their restoration by operative procedure is impracticable; but it may be possible to make a passage-way directly into the lachrymal sac, and by repeated probings cause it to remain patulous, as was done in the case to which allusion has been made under the head of Atresia of the Puncta. The circumscribed strictures may usually be overcome by the passage of a small lachrymal probe or of the straight probe shown in Fig. 182. Division of the canaliculus may be called for if the stricture is difficult to overcome or is disposed to recur.

Dacryoliths occasionally form in the canaliculi. They were formerly supposed to be simply concretions of lime, but are now known to be composed in great part of a fungus believed by some investigators to be identical with the *leptothrix buccalis*. Cohn, however, denies this, and suggests the name *streptothrix Försteri*. Goldzieher has met with cases in which a cilium occupied the center of the dacryolith, and was probably the exciting cause of its development. The presence of dacryoliths in the canaliculus, which may be detected by the circumscribed swelling to which they give rise, causes epiphora and may excite conjunctivitis. Their early removal, which may necessitate division of the canaliculus, is indicated.

Polypi have been known to form in the canaliculi, and may project through the puncta. They should be removed, the canaliculus, if necessary, being divided, as soon as their presence is recognized.

Foreign bodies, such as eyelashes, bits of the beard of wheat and barley, occasionally find their way into the canaliculi, where they may remain for a long time, causing considerable annoyance. If they project through the puncta, they may be seized with forceps and easily withdrawn; otherwise division of the canaliculus may be necessary to effect their removal. In one instance (reported by Haffner) an *ascaris lumbricoides* was removed from the lower canaliculus.

Dacryocystitis.—Inflammation of the lachrymal sac, or dacryocystitis, occurs as a *chronic* and as an *acute* affection. The former is usually denominated *blennorrhoea of the lachrymal sac*, while the latter is often spoken of as *abscess of the sac*.

Etiology and Symptoms.—Primary inflammation of the lachrymal sac is of rare occurrence. It is oftenest met with in the new-born, usually in the form of a mild blennorrhoea; it is said to occur in strumous children, and it may be excited by external violence or the entrance into the sac of an irritant

fluid. In the large majority of cases dacryocystitis is secondary to, and dependent upon, stricture of the nasal duct.

Although inflammation of the lachrymal sac frequently gives rise to conjunctivitis and keratitis, the reverse rarely happens. The truth of this statement is strikingly illustrated in gonorrheal conjunctivitis. Although the gonococci doubtless find their way in great numbers into the lachrymal sac, dacryocystitis as a complication of gonorrheal conjunctivitis is, so far as the writer can learn, practically unknown.

On the other hand, there is the closest pathological sympathy between the lachrymal sac and duct and the nasal passages, and doubtless in a majority of cases dacryocystitis is traceable, directly or indirectly, to nasal disease. Such being the case, it is not surprising, when one bears in mind how almost universally prevalent catarrhal affections of the nasal mucous membrane are, that inflammation of the lachrymal sac and nasal duct should be of comparatively frequent occurrence.

Watering of the eyes is a usual symptom of acute rhinitis, and probably in most pronounced cases of this affection the mucous membrane lining the lachrymal drainage apparatus participates to a greater or less extent in the general nasal catarrh. With the subsidence of the rhinitis the lachrymal catarrh and the transient occlusion of the nasal duct which has probably accompanied it usually disappear, and the parts return to a healthy condition.

Exceptionally, however, because of the severity of the inflammation, the occurrence of a second or third attack before the first has been recovered from, a congenital narrowness of the nasal duct, or a peculiar susceptibility of the lachrymal passages to disease (a susceptibility which is not infrequently inherited), the inflammation of the walls of the duct does not subside with the nasal affection, and presently assumes a more serious character.

Under such circumstances the inflammation, which at first was simply a catarrh of the mucous membrane, invades the underlying periosteum, and the temporary occlusion of the duct from engorgement of the submucous plexus of veins gives place in time to a permanent stenosis from periosteal and osteal thickening. In this way—and, perhaps, still more frequently from the extension of *chronic* inflammatory affections of the nose to the lachrymal passages—*stricture of the nasal duct*, which, as has been said, is the usual forerunner of dacryocystitis, commonly arises.

The chronic nasal affections of inherited and acquired syphilis, it may be remarked, are especially liable to involve the lachrymal apparatus. Blows upon the bridge of the nose or about the inner angle of the eye may not only cause inflammation of the lachrymal sac, as has been indicated, but may lead to the development of stricture of the nasal duct.

When once the occlusion of the duct is complete, the tears, mucus, and epithelial debris which collect in the lachrymal sac are invaded by bacteria and undergo putrefactive changes. This soon leads to inflammation of the lining membrane of the sac, and the condition known as *chronic dacryocystitis* or *blennorrhœa of the lachrymal sac* becomes established.

This condition does not give rise to pain, but the attendant epiphora and regurgitation of mucus and muco-pus through the puncta into the conjunctival sac not only cause great annoyance, but, as has been stated, may bring on chronic conjunctivitis and blepharitis, and even corneal inflammation.

The accumulation of tears and mucus frequently leads to a perceptible distention of the sac (*mucocele*), which disappears under slight pressure with the tip of the finger, the contents of the sac usually regurgitating through the

puncta, but exceptionally, when the stenosis of the duct is incomplete, escaping into the nose (Fig. 183).

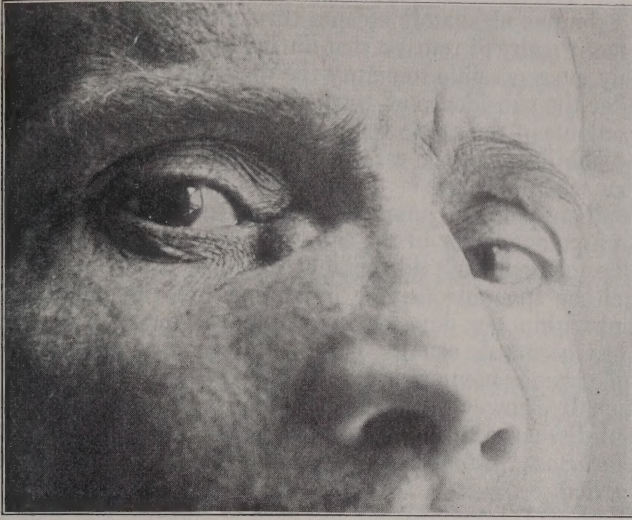


FIG. 183.—Mucocoele; fracture of superior maxilla; exostoses of nasal bones. (Case under care of Dr. de Schweinitz in the Philadelphia Hospital.)

In some instances this state of chronic catarrhal inflammation lasts indefinitely, without undergoing appreciable change; but in others, through the influence of cold, a slight traumatism, the entrance into the lachrymal sac of pyogenic organisms of unusual virulence,¹ some constitutional disorder or, as seems to happen not infrequently, the sudden occlusion of the canaliculi at their point of junction with the sac, the inflammation undergoes a sudden and acute aggravation.

Severe pain, accompanied by great distention of the sac and marked edema of the lids and surrounding parts, comes on, and decided evidences of constitutional disturbance, such as fever, loss of appetite, sleeplessness, etc., manifest themselves. These are the symptoms which characterize *acute dacryocystitis* or *abscess of the lachrymal sac* (Fig. 184), and which in many cases of stricture of the nasal duct recur from time to time so long as the occlusion of the duct is permitted to remain.



FIG. 184.—Acute dacryocystitis.

After several days of intense suffering the integument over the sac assumes a yellowish appearance, becomes thinned, and, if left to itself, usually gives way at a point just below the

¹ Besides the commoner pyogenic organisms, the streptococcus pyogenes has been found in dacryocystitis, especially, it is claimed, in the acute exacerbations.

internal palpebral ligament, permitting the purulent contents of the sac to escape, and affording the individual immediate and almost complete relief from his sufferings. Exceptionally, the inflammation subsides without perforation of the sac, and the pus ultimately escapes through the canaliculi and puncta.

It is a fact worthy of remark that during an attack of acute dacryocystitis it is scarcely ever possible to empty the distended sac by external pressure, although after the subsidence of the acute inflammation pressure will usually cause the contents of the sac to regurgitate through the canaliculi and puncta, as, in all probability, was the case before its onset. From this it would seem probable that when the sac is unduly distended a valve-like closure of the canaliculi at their point of juncture with the sac occurs; and it may be that this is often a potent factor in the causation of acute dacryocystitis.

After the contents of the acutely inflamed lachrymal sac have been evacuated, either spontaneously or by an incision, the inflammation rapidly subsides, and within ten days or two weeks the opening through which the discharge has occurred usually closes, and the sac resumes its previous condition of chronic blennorrhea.

Exceptionally, however, the cicatrization of the opening is prevented by the continual discharge through it of tears and muco-pus, and the condition known as *lachrymal fistula* becomes established—to remain, perhaps, for an indefinite period.

Treatment of Dacryocystitis.—There is but one effectual and rational way of curing dacryocystitis, and that is by eradicating the stenosis of the nasal duct upon which, as has been stated, it almost invariably depends.

During an attack of acute inflammation of the sac, and for some days after its subsidence, operative interference with the strictured duct is out of the question, and we must, for the time being, content ourselves with the administration of anodynes and such other constitutional remedies as the condition of the patient may seem to call for, and the local application of soothing fomentations, to be followed, in all probability, by an early incision through the anterior wall of the sac, below the internal palpebral ligament. Such an incision, if made in the direction in which the skin tends to wrinkle—that is, from above and toward the nose downward and outward—does not leave a perceptible scar, and gives a freer exit to the retained pus than does an incision into the sac along the canaliculus.

A pad of gauze wet with a lotion of opium and boric acid (ext. opii, gr. x–xv, acid. boric., gr. lx, aq. destil., ℥iv), and covered with a piece of rubber “protective” to prevent evaporation, forms a cleanly and convenient substitute for a poultice, and will be found a very useful application in these cases.

In chronic blennorrhea of the sac, if for any reason it is not practicable to treat the strictured nasal duct, a considerable measure of relief may be obtained from slitting the lower canaliculus and prescribing a collyrium, either of bichlorid of mercury (1 : 12,000) or of alum (gr. ij) and boric acid (gr. x–xv to an ounce), to be dropped into the eye two or three times a day, explicit instructions being given to empty the sac of its contents by pressure with the finger-tip before each instillation of the drops.

It is well to bear in mind that abscesses occasionally occur in the neighborhood of the lachrymal sac (*prelachrymal abscess*), which, from their appearance only, cannot always be distinguished from dacryocystitis. The history of the case, however, showing the absence of pre-existing symptoms of lachrymal disease, will usually make the diagnosis plain.

Stricture of the Nasal Duct.—As to the *etiology* of obstructions of

the nasal duct, little need be added to what has already been said upon this subject in treating of Dacryocystitis. How often syphilis, both inherited and acquired, is a factor in their causation, especially when it has invaded the nasal passages, has already been pointed out.¹ Syphilitic gummata have been met with in the lachrymal sac, as well as in the duct. Tuberculosis of the nose, through extension to the lachrymal passages, has been known to cause stenosis of the duct, and polypi of the lachrymal sac to produce a like effect. The exanthematous fevers—measles, scarlet fever, and small-pox—also may lead to occlusion of the duct through the inflammation of the nasal mucous membrane which attends them.

As to the *location of the strictures*, there is no part of the duct in which they are not frequently encountered, although their most common situation is at its upper extremity. Multiple stricture, at least in cases of long standing, is the rule.

As the strictures are the outcome of periosteal inflammation, they are almost invariably, in part at least, of bony structure. They may be circumscribed and annular in form (a thin bony septum being sometimes encountered), or ill defined and of wide extent, involving a considerable part of the length of the duct. When situated at the lower extremity of the duct their existence is not so easily recognized, and it may happen that a mistake of this kind will render the treatment of no avail.

The stenosis of the lachrymal duct which occurs in the new-born is usually of an entirely different character, being due simply to tumefaction of the membranous walls of the canal, and in consequence it generally yields readily to treatment, operative interference being only exceptionally called for. A similar condition is occasionally met with in adults, and may be suspected if the symptoms of occlusion of the duct are of but short duration.

Prognosis and Treatment.—The confessedly poor results which, in the main, have been obtained in the treatment of strictures of the nasal duct are, in the writer's opinion, attributable chiefly to the inadequate size of the probes which are commonly employed to overcome the stenosis. The great merit of the invaluable operation devised by Bowman of slitting the canaliculus as a preliminary step in the treatment of lachrymal strictures (see page 596) is that it permits the passage of probes sufficiently large to overcome entirely the stenosis and restore completely the normal caliber of the canal. Nevertheless, Bowman himself fell far short of appreciating this fact, as is shown by the small size of the probes which he employed,² and, owing to an unreasoning conservatism, which those who have emancipated themselves from its influence can scarcely comprehend, the same may be said, even at the present day, of the great majority of those who have followed his plan of treatment. The absurdity of attempting with a probe of 1.50 mm. diameter to restore to its normal dimensions an occluded canal which in health has an average diameter (measured in its shortest axis) of somewhat more than 4 mm.,³ it would seem should be evident to all; but experience shows that such is far from being the case.

¹ Seventeen out of two hundred and forty cases of stricture of the nasal duct in Galezowski's clinic were found to be of syphilitic origin.

² The largest of Bowman's probes, No. 6, had a diameter of about 1.3 mm., or, according to Soelberg Wells, about $\frac{1}{20}$ of an inch. Dr. Isaac Hays of Philadelphia, it may be remarked, had previously used a slightly larger probe than this (1.50 mm.) without dividing the canaliculus.

³ See paper by the writer upon "The Use of Large Probes in the Treatment of Strictures of the Nasal Duct," *Trans. Medical and Chirurg. Faculty of Maryland*, 1877, p. 154; also measurements of the nasal duct given by Mr. Henry Power in "Lectures upon Diseases of the Lachrymal Apparatus," published in the *London Lancet*, 1886, vol. ii.

The accompanying illustration (Fig. 185), which represents graphically the results of measurements of the nasal duct made by the writer, and described in the paper to which reference has been given, is in this connection instructive:

- Bowman's No. 6 probe; diameter = 1.50 mm.
- Theobald's No. 16 probe; diameter = 4 mm.
- Average size of 10 adult nasal ducts, cadaver; diameter = 4.47 + mm.
- Largest of 10 adult nasal ducts, cadaver; diameter = 5.25 mm.
- Largest of 70 bony nasal ducts; diameter = 7 mm.

FIG. 185.—Diameters of probes and nasal ducts.

Besides the treatment by means of probes, there are other methods of dealing with stenosis of the duct and its accompanying dacryocystitis which have their advocates. Although the *gold canula* of Wathen and Dupuytren is probably scarcely ever used at the present day, there are many who still employ *styles* of different patterns made of lead, silver, or aluminum, and others who practise division of the strictures as recommended by Stilling, to whom the credit of having originated this method of treatment is usually given. The interesting fact, however, has recently come to the writer's knowledge that as early as 1846 the late Prof. Nathan R. Smith of Baltimore dealt with lachrymal strictures in this manner, and devised a knife of peculiar pattern for this especial purpose.¹

In intractable cases of dacryocystitis dependent upon occlusion of the nasal duct, which have failed to yield to less radical measures, removal of the lachrymal gland (see page 596), and also excision of the lachrymal sac (see page 597) or its destruction by means of caustics or the galvano- or thermo-cautery (see page 597), are practised by some ophthalmic surgeons, and, it is claimed, with excellent results. The writer has had no experience with these last-mentioned procedures, not having encountered cases in which such radical measures seemed to be indicated. As to the employment of styles, his experience with them has not been satisfactory, and leads him to regard them as of limited applicability, being useful only when time will not permit of the proper carrying out of the probing treatment.

Briefly described, the writer's method of dealing with strictures of the nasal duct, which he has employed almost without exception in all cases that have come into his hands during the past twenty years, and which has yielded, as a rule, most gratifying results, is as follows:

The *lower*² canaliculus, after having been slightly dilated by the passage of a No. 1 or No. 2 probe (cocain having been previously instilled into the conjunctival sac), is divided well up to its juncture with the lachrymal sac with Weber's beak-pointed canaliculus knife (Fig. 415), or, preferably, with

¹ See the writer's article upon "Diseases of the Lachrymal Apparatus," in a *System of Diseases of the Eye*, edited by Norris and Oliver, vol. iii.

² Some surgeons prefer to divide the *upper* canaliculus and to introduce the probes through it, but this seems to the writer a more difficult and comparatively awkward procedure.

the modification of the knife represented in Fig. 416. An effort is then made to pass into the sac and through the duct a No. 5 or No. 6 of the writer's series of lachrymal probes (usually the former)¹ (see Fig. 419, page 598). If the probe enters fairly into the lachrymal sac, any reasonable amount of force which may be necessary to pass it through the occluded duct to the floor of the nose is employed without hesitation, care being exercised that it does not take a wrong course. If, owing to a constriction at the juncture of the canaliculus and the sac (a condition which is not infrequently met with, and which occasionally greatly complicates the treatment), the point of the probe is arrested and prevented from entering the sac, a smaller probe, No. 4 or No. 3, is tried. If neither of these can be introduced, it is best to desist from further efforts and to wait for forty-eight hours, when very often the difficulty previously experienced in entering the sac will be found to have disappeared. If this does not prove to be the case, an opening is drilled through the constriction with the sharp-pointed, straight probe (Fig. 182), or, the lid being kept well upon the stretch, a No. 5 probe is passed along the canaliculus to the point of resistance and is then turned vertically and forced into the sac—a procedure which, if possible, should be avoided, as it may result in the making of a false passage directly from the canaliculus into the duct. Exceptionally, the constriction must be divided with a sharp-pointed knife, the old-fashioned cataract knife of Sichel being especially convenient for this purpose.

The probe, after being passed entirely through the duct to the floor of the nose, is allowed to remain *in situ* for from ten to twenty minutes. The probing is repeated during the early stages of the treatment every other day, usually a size larger probe being passed each time. The size of the largest probe which it is desirable to use will of course vary in different cases, but there are very few in which it is well to stop short of No. 14, for it is to be borne in mind that our purpose is to obliterate the stricture completely (not simply to make a small opening through it) and to restore the normal caliber of the duct. In about two-thirds of all his cases (including children as well as adults) the writer introduces No. 16. In passing the larger probes considerable force is sometimes employed. This has been found not only to be permissible, but, instead of doing harm, as many maintain must necessarily be the case, its effect upon the carious walls of the duct is distinctly curative, the result being not unlike that produced by the curetting of diseased bone in other parts of the body.

When as large a probe has been introduced as is deemed necessary, the interval between the probings is gradually increased, first to three or four days, then to a week, a fortnight, and finally to a month or two months; and when several of these longer intervals have elapsed without any tendency to recontraction having manifested itself, the case is dismissed with full assurance that a permanent cure has been effected. Including these longer intervals the treatment frequently extends over a period of eight or ten months; but the active treatment, involving the frequent probings, is comprised within as many weeks.

Electrolysis has been tried by the writer to a limited extent, to promote the more rapid absorption of lachrymal strictures; but, so far as could be judged, its effect was inappreciable. The chloride-of-silver, "dry-cell,"

¹ The series comprises sixteen sizes. No. 1 has a diameter of 0.25 mm., and the sizes increase by 0.25 mm., the largest of the series, No. 16, having a diameter of 4 mm. The smaller sizes, from No. 1 to No. 6, are made of coin-silver; the larger sizes, from No. 8 to No. 16, of aluminium or of copper, nickel-plated.

battery is convenient for this purpose. From eight to twelve cells may be used, the negative pole being connected with a probe which has been introduced into the duct, while a moist sponge connected with the positive pole is held in contact with the cheek.

No attempt is made by means of syringes to inject antiseptic or other solution into the lachrymal sac, but, instead, a collyrium is prescribed, which the patient is instructed to drop into the inner corner of the eye three times a day, after having pressed out the contents of the sac with the finger-tip. The collyria which have been found most useful are a solution of bichlorid of mercury (1 : 12,000) and one of alum and boric acid, containing 2 per cent. of boric acid and one-half of 1 per cent. of alum. Formaldehyd (1 : 2000) is much employed by some surgeons, as are all of the usual antiseptic and astringent collyria.

The presence of a lachrymal fistula, even when accompanied by caries of the underlying bone, has not seemed to call for especial treatment. The fistula has been found to heal promptly, and the carious bone to become re-covered with periosteum as soon as the stenosis of the duct has been overcome by the passage of the large probes.

The frequent dependence of lachrymal disease upon nasal catarrh is kept constantly in mind, and treatment is directed to the nasal passages whenever it seems to be indicated. For this purpose a weak solution of bichlorid of mercury (1 : 5000), to which is added a small quantity of chlorid of sodium and glycerin, applied to the nose several times a day by means of a hand-atomizer, has been found especially efficacious. (For full particulars in reference to measures suited to such conditions see sections devoted to diseases of the rhino-pharynx.)

The length of time during which the probing must be kept up varies considerably in different cases; but it is a safe rule not to discontinue the use of the probe altogether as long as there is any evidence of dacryocystitis or any roughness of the walls of the duct noticeable on passing the probe. In obstinate cases, however, it is well to lengthen the interval between the probings, as it sometimes happens that the inflammation is kept up by the too frequent introduction of the probe. In several instances, when patients from a distance could not remain under treatment as long as was thought desirable, it has been found practicable to teach them to probe their own nasal ducts with the large probes which had been previously introduced, cocain being first instilled to minimize the pain. In this way relapses, which otherwise might have occurred from the too early discontinuance of the treatment, have been

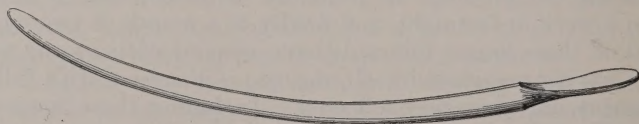


FIG. 186.—Modified form of lachrymal probe for use by patients (actual size).

avoided. The probe represented in Fig. 186 was devised by the writer for this purpose, and has been found very useful.

In the transient occlusion of the nasal duct which occurs in the new-born operative interference, as has been stated, is seldom called for; nevertheless, if the collyria of bichlorid of mercury, of alum and boric acid, and, perhaps, a weak solution (gr. $\frac{1}{4}$ to $\frac{3}{32}$) of nitrate of silver, have been tried perseveringly without effect, it may become necessary to divide the canaliculus and introduce a probe. The outcome of this treatment is usually very satis-

factory, and it is seldom necessary to repeat the probing oftener than four or five times. In a case of this character in a child fifteen months old recently under treatment, and in which a complete cure was effected, the duct was probed in all ten times, No. 12, the largest probe used, being introduced upon five successive occasions.

The writer's experience with the radical treatment of strictures of the nasal duct by the use of large probes now extends over a period of nearly twenty years, during which time he has employed it in a large number of cases, and has had the opportunity of seeing many of them, from time to time, for long periods after the discontinuance of the probing; and his observation is that the cases in which the treatment is systematically carried out in the manner which has been described are, with comparatively few exceptions, completely and permanently cured.

DISEASES OF THE CONJUNCTIVA.

BY JOHN E. WEEKS, M. D.,

OF NEW YORK CITY.

Congenital Anomalies of the Conjunctiva.—Pigment-patches, like moles, sometimes appear on the conjunctiva, accompanying moles of the face.

Dermoid tumors develop on the ocular conjunctiva (often extending on to the cornea), at the caruncle, and at the upper outer quadrant of the globe (see page 329). They are at times associated with coloboma of the lids. They may be pigmented. Dermoid cysts have also been observed.

Telangiectatic patches may appear on the caruncle and also on the palpebral conjunctiva. They are flat, slightly elevated, bright red in color, and often accompany telangiectatic patches on the lids and face.

Cavernoma of the conjunctiva also exists as a congenital growth. The color is dark blue, and the conjunctiva is bulged forward at the affected part. When the head is lowered or the child cries or coughs the tumor increases in size.

Small subconjunctival lipomata may accompany congenital coloboma of the lids or may exist alone.

Well-developed bone-tissue has been observed situated beneath the ocular conjunctiva, between the margin of the cornea and the outer commissure.

The caruncle may present an abnormal development of hair (*trichosis carunculæ*). Congenital duplication of the caruncle has been reported by Stephenson.

Hyperemia of the Conjunctiva (*Dry Catarrh*).—This condition usually affects the palpebral conjunctiva, and is manifested by a persistent redness with no appreciable thickening. The posterior system of conjunctival vessels is involved.

Etiology.—The causes of this affection are numerous, and comprise the entrance of minute irritating particles into the conjunctival sac, exposure to strong winds, cold, heat, and glare of light. Conjunctival hyperemia may be produced by use of the eyes with poor illumination, eye-strain from errors of refraction or muscular irregularities, by too continuous use of the eyes on fine work, by indigestion, alcoholic beverages, rheumatic gout, vaso-motor disturbances, nasal catarrh, lachrymal disease, blepharitis marginalis, acute exanthematous fevers, etc.

Pathology.—There is little change in the tissues; the blood-vessels are enlarged and overfull, and there is a scanty small cell-infiltration and increase in nuclei.

Symptoms.—The lids feel heavy and hot; movements of the eye are painful; there are increased lachrymation and slight photophobia. Attempts to use the eyes by artificial light are accompanied by distress.

Diagnosis and Prognosis.—Redness of the conjunctiva without discharge

other than increased lachrymation, and without other appreciable change in the conjunctiva, suffices to establish a diagnosis. The *prognosis* is favorable, provided the cause can be removed.

Treatment.—This should include the prevention of the entrance of foreign substances into the eye, and the correction of habits and systemic conditions that contribute to the continuation of the hyperemia. Errors of refraction and muscular defects should be corrected. Bathing the conjunctiva with a solution of boric acid, 2 or 3 per cent., three or four times a day, usually suffices for the local treatment. Strong astringents are not advisable.

Conjunctivitis (Ophthalmia).—This term embraces a number of diseases of the conjunctiva characterized by increased altered secretion from the surface of the conjunctiva, pronounced distressing symptoms, and transient or permanent pathological changes in the membrane.

Simple Conjunctivitis (Catarrhal Ophthalmia).—There is a relatively large number of forms of conjunctivitis which are mild in character and tend to spontaneous recovery, without serious complications, which may be placed in this class. They are characterized by slight swelling of the lids and conjunctiva and the presence of a muco-purulent secretion. The specific disease known as *acute contagious conjunctivitis*, usually considered under this head, will be described separately.

Etiology.—(a) *Mechanical or traumatic* varieties are caused by the presence of dust or other irritating substances, as certain kinds of pollen, fish-scales, foreign bodies of any description, insects and parts of insects.

(b) *Associate* varieties accompany the eruptive fevers (measles, scarlet fever, small-pox), influenza, acute coryza, facial erysipelas, eczema, and blepharitis marginalis. The *pneumococcus* of Fränkel (Fig. IV., Plate 2) has been described by Morax, Parinaud, and others as an infrequent, and by Gifford¹ as a frequent, cause of simple conjunctivitis.²

Symptoms.—The development of muco-purulent secretion is preceded by burning sensations, increased lachrymation, hyperemia, and slight swelling of the palpebral conjunctiva and transition fold. More or less marked swelling of the lids occurs, movements of the lids are painful, and photophobia with inability to use the eyes develops. Frequently one eye alone is affected, particularly in those cases having a mechanical origin.

Diagnosis and Prognosis.—Often the history of the case is all-sufficient. Examination of the conjunctival sac may disclose the presence of an irritating substance in addition to the muco-purulent secretion. In doubtful cases a microscopical examination of the secretion will serve to decide its character. The prognosis as to duration is favorable in all cases where the cause can be discovered and removed. No serious impairment of vision occurs.

Treatment.—The causes that produce the disease should be sought for and removed, when rapid recovery even without local medication often will take place. However, a cleansing wash, as a solution of boric acid, or of sublimate 1:15,000, may be used every two or three hours to advantage.

¹ *Archives of Ophthalmology*, vol. xxv., 1896, p. 314.

² The affections of the conjunctiva which are due to a known specific micro-organism are: Acute conjunctivitis described by Morax—*pneumococcus*; acute contagious conjunctivitis—small bacillus, first seen by Koch in 1883, and cultivated and proved to be the specific micro-organism by Weeks in 1886, without knowledge of Koch's observation; gonorrheal conjunctivitis—diplococcus of Neisser; diphtheritic conjunctivitis—Klebs-Löffler bacillus; tubercular conjunctivitis—tubercle bacillus of Koch; and leprosy of the conjunctiva—leprosy bacillus.

There are a number of affections of the conjunctiva in which a specific micro-organism probably exists, but which has not yet been positively identified; of these may be mentioned phlyctenular conjunctivitis, trachoma, membranous conjunctivitis, and xerosis epithelialis.

After the acute stage is passed an astringent stimulating collyrium of zinc sulphate, alum, or nitrate of silver, in the strength of one grain to the ounce, may be instilled once daily until all secretion has disappeared.

Acute Contagious Conjunctivitis (*Acute or Epidemic Catarrhal Conjunctivitis*; *Muco-purulent Conjunctivitis*; "*Pink Eye*" (vulgarly)).—This is an acute, highly contagious, muco-purulent inflammation of the conjunctiva, accompanied by some swelling of the lids. A period of incubation precedes the acute stage; both eyes are usually affected. No age is exempt, except perhaps the first ten days of life. The affection is met with most frequently in the spring and fall months, often becoming epidemic. So far as is known it is prevalent throughout almost if not quite the entire world.

Etiology.—This disease is due to the presence of a specific micro-organism, a bacillus, in the conjunctival sac. A careful study of this micro-organism was first made by the writer¹ in 1886, and his work has since been confirmed by Kartulis,² Morax,³ and others. The bacillus resembles that of mouse-septicemia, measuring 0.25 micro-millimeters in thickness (Figs. II. and III., Plate 2).

Pathology and Pathological Anatomy.—The posterior and anterior systems of blood-vessels are congested, and there is apparently an increase in the number of capillaries and arterioles. The conjunctiva at the transition folds becomes thickened through the medium of the enlarged vessels, slight serous effusion, and the presence of leukocytes in moderate number in the conjunctival tissue. Small transfusions of blood occur in the ocular conjunctiva from the smaller vessels of the anterior vascular system.

Microscopical examination of the conjunctiva at the fornix discovers a slight infiltration of leukocytes at the base of the epithelial layer and between the epithelial cells, a moderate edematous condition of the tissue, and the presence of a few bacilli disposed in small groups in the epithelial and very superficial conjunctival layers. The secretion contains many bacilli, free and aggregated, on or in the leukocytes.

Symptoms.—About thirty-six hours after the inception of the contagium the patient experiences a mild burning sensation in the lids, which are stuck together on waking in the morning; lachrymation is slightly increased. On the morning of the third day the lids are glued together with a thick layer of muco-pus. They are swollen, sometimes intensely so, and the patient suffers from a sensation as of a foreign body in the eye. Some photophobia is experienced. Use of the eyes is accompanied by pain; vision is blurred by the presence of the secretion. The palpebral conjunctiva is deeply injected, the transition fold thickened, and the ocular conjunctiva presents a bright-red appearance, a peculiarity which has given the disease the popular name of "*pink eye*." At the end of the third day the affection is usually at its height.

In the greater number of cases the swelling of the lids does not become intense, but in a few this symptom is pronounced, and when accompanied by pseudo-membrane the disease may be mistaken for diphtheria.

The secretion seldom loses its ropy character, due to the presence of mucin, but in some cases it becomes quite purulent, resembling the discharge of gonorrheal conjunctivitis. There is seldom any chemosis, although the ocular conjunctiva is intensely injected. Close inspection will disclose the

¹ *Archives of Ophthalmology*, vol. xv. No. 4, 1886; *N. Y. Med. Rec.*, May 21, 1887.

² *Centralbl. f. Bakt. u. Parasitenk.*, 1887, p. 289.

³ *Récherches bactériologiques sur l'Étiologie des Conjunctivites aiguës, etc.*, Paris, 1894.

PLATE 2.

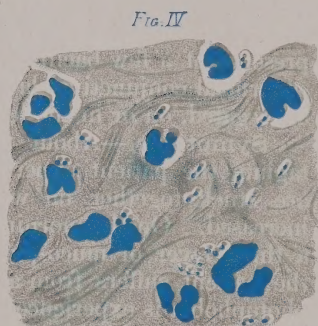
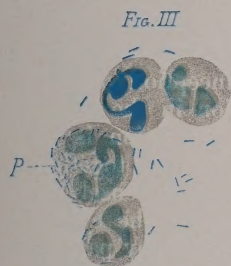
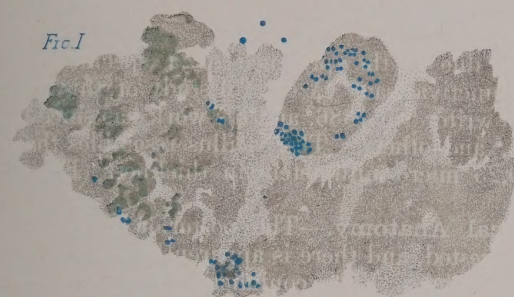


FIG. I.—Discharge from right eye in a case of purulent conjunctivitis; gonococci numerous in cells (Stephenson).

FIG. II.—Bacillus of Weeks in pure culture (from a photograph).

FIG. III.—Conjunctival secretion from acute contagious conjunctivitis; polynuclear leukocytes with the bacillus of Weeks; P, phagocyte containing bacillus of Weeks; immers. $\frac{1}{2}$, oc. iii. (Morax).

FIG. IV.—Secretion from a case of conjunctivitis, showing pneumococci; immers. $\frac{1}{2}$, oc. iii. (Morax).

presence of many small transfusions of blood in the ocular conjunctiva: this is such a common symptom that Nettleship has given the affection the name of "*hemorrhagic catarrhal conjunctivitis*."

The acute stage, which is often accompanied by slight rise of temperature and frontal headache, lasts from four to ten days. The discharge gradually diminishes in quantity, becomes thicker, and collects in little yellow masses at the inner canthi. The swelling of the lids and conjunctiva and the painful symptoms gradually subside, and recovery usually occurs in from two to three weeks. In the subacute stage the conjunctiva at the transition folds presents a swollen, succulent condition, with enlargement of the papillary body and some follicular hypertrophy.

Diagnosis and Prognosis.—A history of the presence of the affection in all or a number of the members of a family, or of its epidemic character in institutions, will aid much in establishing a diagnosis. The very yellow mass of secretion at the inner canthus is quite characteristic. Acute contagious conjunctivitis may be mistaken for purulent conjunctivitis, and, when a pseudo-membrane forms, as it does in about 4 per cent. of the cases, for diphtheritic conjunctivitis. The microscope may be depended on to make the diagnosis clear in doubtful cases.

In the greater number of cases recovery ensues without leaving a trace of the disease; relapses and recurrences are frequently observed. One attack does not ensure immunity. Phlyctenulæ may develop in the later stages or trachoma may follow, but these conditions must be regarded as secondary diseases grafted on the primary disease by added infection. The cornea is rarely affected. In adults the attack is more severe than in children. The disease is contagious as long as secretion is present.

Treatment.—As the disease is very contagious, isolation should be resorted to if possible. Bathing appliances should be separate. In all cases where large numbers of individuals are aggregated quarantine should be rigidly enforced, and persevered in until all traces of secretion have disappeared, and even for a few days after that period.

For the first three to five days of the acute stage cold applications are indicated. These may be applied as follows: Thin pads of absorbent cotton, $1\frac{1}{2}$ inches in diameter, or pieces of linen, $1\frac{1}{2}$ inches square and two or three layers in thickness, to the number of ten or twelve, should be placed on a cake of ice over which a thin napkin is spread, and a pad transferred to and from the eye sufficiently often to keep the lids cool—every two minutes. In severe cases the cold applications should be continuous; in mild cases it will suffice to keep up the applications through the daytime.

While this is being done the eye should be cleansed every half hour if the secretion is profuse, less often if the secretion is scanty, with some bland antiseptic solution. Boric acid, 2 or 3 per cent., or the bichlorid of mercury, 1:15,000, may be employed. When the acute stage is subsiding the cold applications should be discontinued, the bathing continued, and in addition a more energetic germicidal astringent may be employed. Nitrate of silver, in the solution of 0.5 to 1 per cent., is excellently adapted for this purpose. The application may be made once in twenty-four hours, and may be continued with less frequency until the secretion ceases. Other topical applications are—alum (gr. 1- $\bar{f}\bar{3}\bar{j}$), acetate of lead (gr. 1- $\bar{f}\bar{3}\bar{j}$), sulphate of zinc (gr. 1- $\bar{f}\bar{3}\bar{j}$), peroxid of hydrogen, formalin (Schering's solution—1:200 to 1:500).

Bandaging the eyes and the application of poultices of tea-leaves, oysters, scraped potatoes, bread and milk, and other domestic concoctions should be

avoided. These only serve to retard recovery, and in many cases increase the inflammation.

Purulent Conjunctivitis (*Acute Blepharitis of the Conjunctiva*).—The term purulent conjunctivitis properly applies to all forms of conjunctivitis in which the discharge is more or less copious and comparatively free from mucin. This condition obtains in certain cases of acute contagious conjunctivitis, in some cases of traumatic conjunctivitis, in the forms induced by the application of a poultice of tea-leaves in simple conjunctivitis (*tea-leaf conjunctivitis*), and in the later stages of diphtheritic conjunctivitis. As commonly employed, it refers to the conjunctivitis induced by the presence of the *gonococcus of Neisser*, and is usually considered under the terms *gonorrheal conjunctivitis* and *conjunctivitis neonatorum*.

Gonorrheal Conjunctivitis.—This disease occurs in men much more frequently than in women. It is characterized by marked swelling of the lids and copious discharge of purulent secretion from the conjunctiva.

Etiology.—The gonococcus of Neisser (see Fig. I., Plate 2) in secretion from a diseased mucous membrane is brought in contact with the conjunctiva. Probably the most frequent manner of its conveyance is by means of the finger from a urethral or vaginal gonorrhea. The use of a common washing-bowl, towels, etc. may serve to communicate the disease. It is not probable that the contagium can be carried through the air. The discharge in gleet, as well as in pronounced gonorrhea, may serve to set up the affection, but it is supposed to be less severe when arising from gleet.

Pathology and Pathological Anatomy.—Engorgement of the vessels of the palpebral and ocular conjunctiva rapidly develops. An infiltration of leukocytes into the superficial layers of the entire conjunctiva and edema induced by a serous and in some cases a fibrinous exudation occur early. The conjunctival epithelial layer is swollen and uneven. The pathogenic micro-organism grouped in or on the leukocytes in the characteristic manner is seen

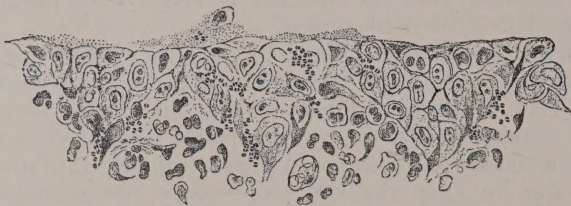


FIG. 187.—Gonococci in the tissues of the conjunctiva (Bumm).



FIG. 188.—Gonococci free and on the cells (Bumm).

in the superficial layers of the conjunctiva (Fig. 187). The secretion contains the gonococci, which are found free and on the pus-cells (Fig. 188).

Symptoms.—The *stage of incubation*, which lasts from twelve to forty-eight hours, is succeeded by the acute stage. The lids swell rapidly, and sometimes enormously, taking on a dark-red hue. The vessels of the conjunctiva become deeply congested, the conjunctiva red and swollen. There are a gritty sensation and smarting and burning of the lids. The increased weight of the lids produces a continuous dull pain in the eyes. The *acute stage* reaches its height in two or three days, at which time the swelling of the lids in typical cases is intense. The upper overlap the lower lids; from beneath the margins of the upper lids the secretion, which at first is watery and flaked with pus, and later becomes thick and creamy, oozes out on to and flows down the cheek. At times the secretion is retained in the conjunctival sac, producing much pain by pressure on the globe.

The conjunctiva of the tarsus and transition fold becomes much thickened and presents a deep-red, velvety appearance. The ocular conjunctiva becomes very edematous, marked chemosis develops, and extravasations of blood are observed in this part of the conjunctiva. The chemotic tissue may overlap the cornea, giving lodgement to secretion in the sulcus thus formed, which is difficult to remove, and which serves to macerate and destroy the corneal epithelium, establishing an *ulcer of the cornea*. The chemotic tissue may protrude between the lids.

The acute stage continues from four days to two weeks, and gradually merges into the *subacute stage*. The thickening of the lids is now much less; they are pale, soft, and flabby. The conjunctiva presents a velvety appearance, and is still much hypertrophied; the chemosis is less marked and the secretion less profuse.

What might be termed the *atonic stage* succeeds the subacute stage. The swelling of the lids has subsided, but the conjunctiva of the tarsus and transition folds is left rough, rugose, and presents many papilliform elevations. The secretion is thinner and not so profuse. Use of the eye is difficult. This stage may drift into a *chronic condition* if not treated properly, in which corneal ulcer, trichiasis, entropion, etc. may develop.

Of the complications that develop, *corneal involvement* is most dreaded. Total destruction of the cornea may occur early from interference with the nutrition of that membrane; the cornea loses its luster, becomes gray, and disappears. Loss of the crystalline lens and *panophthalmitis* may follow. Involvement of the cornea is most frequent in the second week of the disease, the ulcer commencing at the margin of the cornea as a grayish, uneven defect which increases in depth and area. *Pseudo-membrane* occurs in a small percentage of the cases. It appears on the palpebral conjunctiva as a result of the deposition of fibrin on a surface from which the superficial epithelial cells have been lost. *Gonorrheal rheumatism* is an infrequent consequence of gonorrheal conjunctivitis.

Diagnosis.—Gonorrheal conjunctivitis presents many degrees of severity. It may be so mild that it readily passes for simple conjunctivitis; or so severe that diphtheria is suspected. The history of the case will assist in making a diagnosis, and microscopical examination will absolutely establish it. The conjunctivitis occurring in young girls with leukorrhea, which is observed from time to time, is often gonorrheal, but, according to some authors, may have other causes.

Prognosis.—In spite of all treatment, a large percentage of cases result in impairment of vision, to a greater or less degree, from corneal complications. If an ulcer appears at the margin of the cornea, and the cornea at this point becomes vascular, recovery without perforation may be looked for. Partial ulceration of the cornea, with or without perforation, may be followed by *partial staphyloma* after the ulcer has healed. *Adherent leukoma* follows perforating ulcer of the cornea, and in rare cases the lens may become adherent to the scar. *Panophthalmitis*, as already stated, may be the result.

Treatment.—*Prophylaxis* as regards other individuals and in regard to the fellow-eye must be first considered. The disease, through the secretion, is extremely contagious; hence immediate isolation should be secured, and should be persisted in until all secretion has disappeared. All dressings and appliances with which the secretion comes in contact should be destroyed or thoroughly sterilized. To protect the fellow-eye a *Buller's shield*, which consists of a watch-crystal held over the eye by means of strips of rubber plaster, should be applied.

Local Treatment.—In the acute stage cold applications should be employed day and night, after the method described on page 277, and the conjunctiva freed from secretion as often as is necessary—every thirty to sixty minutes, with a bland aseptic solution—boric acid 3 per cent. or bichlorid of mercury (1 : 15,000). For the carrying out of this treatment two nurses, a day and a night nurse, are required. If the lids become sore and erosion of the epithelium is threatened, some borated vaselin may be applied after each bathing.

There are many ways of cleansing the eye. The lids may be held gently apart and the warm solution be permitted to run into the conjunctival sac from a piece of absorbent cotton. A pipette may be used to force a stream beneath the lids after they have been gently opened. A speculum with perforated blades has been devised (Andrews) for cleansing the conjunctival sacs, and a lid-retractor which permits the solution to flow through the handle and into the blade, escaping at openings at the margin of the blade, has been made for the same purpose. Except in very skilful hands the instruments devised for cleansing the eyes are dangerous, as they are apt to injure the cornea and induce corneal ulceration.

Applications of cold, which are generally made inadequately, may be made too assiduously and the vitality of the cornea threatened. When too much cold is applied the cornea takes on a steamy appearance and breaks down more easily. If corneal luster fails without evidence of loss of substance, the applications of cold should be intermittent.

Hot applications in the acute stage are contraindicated; they serve to increase exudation and the growth of the gonococcus. In the subacute and atonic stages they may be resorted to with benefit.

As soon as the discharge takes on a purulent character and the lids are less rigid, local applications to the conjunctiva may be made. For this purpose a solution of the nitrate of silver, 1 or 2 per cent., is probably the best. The lids are carefully everted, the secretion removed, and, by means of a piece of absorbent cotton wound around the end of a small applicator the solution is applied to the entire surface of the conjunctiva. This should be followed by applications of cold for one or two hours. The treatment outlined above will suffice to effect a cure in the greater number of cases.

Finely pulverized iodoform is sometimes employed by dusting it into the conjunctival surface two or three times daily. Peroxid of hydrogen has been advocated by Landolt; it is of value as a cleansing and germicidal agent. Sublimate solution, 1 : 500, has been employed recently by applying it to the conjunctiva sufficiently often to hold the secretion in check. Aqua chlorini, formalin (1 : 3000), permanganate of potassium in copious irrigations (1 : 500 or 1 : 1000), are used to irrigate the eye. Dr. Wilson of Bridgeport advocates filling the conjunctival sac with a boric-acid ointment (boric acid gr. xlvij, vaselin $\bar{z}$ j) every one to two hours after cleansing, continuing this treatment until the acute stage has passed: he claims excellent results. In some severe cases Noyes has resorted to scarifying the conjunctiva and brushing in a solution of corrosive sublimate, 1 : 500, repeating the operation in two or three days if the discharge returns.

If corneal ulcer develops, atropin (gr. ij to $\bar{z}$ j) should be instilled two or three times daily. Ehrentaler¹ recommends eserin (gr. ij to $\bar{z}$ j) in those cases of corneal ulcer where congestion of the iris is not present, alternating with atropin in other cases unless perforation is imminent. He avers that the circulation is improved and recovery more certain.

¹ *Münch. med. Wochenschrift*, No. 38, 1892.

When the lids are greatly swollen and tense a free *canthotomy* may be done. This relieves the pressure on the cornea, unloads the blood-vessels, and prevents spasmodic contraction of the orbicularis palpebrarum muscle. In the last stage hot-water bathing, the sulphate of copper or alum-crystal, and tannin may be employed.

Systemic Treatment.—The bowels should be kept free by use of calomel and a saline. Rich food and alcoholic beverages should be forbidden. Opium may be administered if there is much pain.

Conjunctivitis Neonatorum (*Ophthalmia Neonatorum*).—This is a purulent affection of the conjunctiva, accompanied by great swelling of the lids and thick purulent secretion, occurring within a few days after the birth of the child.

Etiology.—That form of the affection which develops within three days after the birth of the child is undoubtedly produced by gonorrheal infection from the vaginal secretions of the mother at the time of birth. In cases that have developed ten days to three weeks after birth other causes are found: the small bacillus of acute contagious conjunctivitis, the pneumo-bacillus, and the Klebs-Löffler bacillus have been observed. The use of soiled towels or napkins about the infant or the unclean hands of mother or attendant may serve as a means of carrying infectious material to the infant's eye. Exceptionally, inoculation *in utero* may occur (*ante-partum conjunctivitis*).

Pathology.—The pathology of ophthalmia neonatorum resembles that of purulent conjunctivitis in the adult, so far as the tissue-changes are concerned.

Symptoms.—Slight puffiness of the lids and a tendency to stick together will be noticed twenty-four or thirty-six hours after birth, and on inspec-

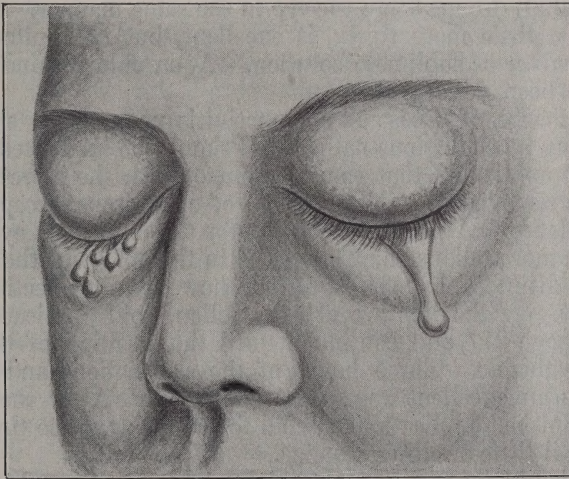


FIG. 189.—Conjunctivitis neonatorum (from a patient in the Philadelphia Hospital under the care of Dr. de Schweinitz).

tion the palpebral conjunctiva will be found to be congested. As a rule, the change in the lids and the presence of secretion are not sufficient to attract attention until the third day, when the secretion has become distinctly purulent and the lids somewhat swollen. At the end of the fourth or fifth day the lids are greatly thickened and of a dusky-red color; the secretion is purulent and quite copious. It either flows out on to the cheek or is retained in greater part by the lids and bursts forth on attempts to separate the lids.

The swelling of the conjunctiva is so intense in some cases that ectropion of the upper lid is produced. Chemosis is not so marked as in purulent conjunctivitis occurring in adults, and involvement of the cornea occurs in a smaller proportion of cases. What has been stated in regard to the symptoms in gonorrheal conjunctivitis of the adult, except as indicated above, applies to conjunctivitis neonatorum.

Diagnosis.—The history of the case and the age of the child will suffice to establish a diagnosis.

Prognosis.—If not properly treated the prognosis is grave, but not to such a degree as in the adult. Properly treated, the prognosis is good. Careful observation of many cases has taught the writer that if the patient is seen *while the cornea is still clear* impairment of vision need not occur, except in the cases in which the affection is very severe and the patient's vitality much impaired. Since the retention of vision depends so much on careful and proper treatment, it is of the greatest importance that the infant should be seen by a competent physician as early as possible. Neglected cases have contributed 20 per cent. to the number of the blind.

Prophylaxis.—The great work done by Credé in Leipzig in reducing the number of cases of conjunctivitis neonatorum from 10.8 to 0.2 per cent. in the infants born at the Lying-in Asylum under his charge shows what may be accomplished by prophylaxis. Credé's method was to drop two drops of a 2 per cent. solution of nitrate of silver into the conjunctival sac of the infant's eyes very shortly after its birth, having first wiped the lids clean. The reaction is quite severe in some cases.

It has been found that equally good results may be obtained with a 1 per cent. solution of nitrate of silver, also with a solution of bichlorid of mercury (1 : 4000) dropped into the eye in the same manner. Normal saline solution, used a little more freely, is excellent, but not quite as efficacious as either the silver or sublimate solution. Aqua chlorini and carbolic acid (1 : 100) have been advocated.

Those in charge of a case of conjunctivitis neonatorum should be cautioned regarding its contagious nature, and should be instructed to destroy or to disinfect all appliances that come in contact with the secretion. The infant should be removed from the presence of all persons except those in immediate attendance. A protective shield for the unaffected eye is not easily made efficient; more reliance may be placed in the ability of the nurse to keep the fellow-eye disinfected. Almost always, however, the affection is bilateral.

Treatment.—If the lids are at all swollen, cold applications, made as described on page 277, and continued until the swelling of the lids partly subsides, are valuable. Three hours of the applications and one hour of intermission is an excellent way of applying cold. After the swelling has markedly diminished applications of cold for one hour, three times daily, may be kept up until little swelling remains.

The pus should be gently removed by lavage with a 2 or 3 per cent. solution of boric acid every half hour or every hour, as long as the secretion is abundant. After the first two or three days applications of a 1 per cent. solution of nitrate of silver may be made by the surgeon to the palpebral conjunctiva, either employing a bit of absorbent cotton on a small applicator or a camel's-hair brush, once in twenty-four hours. As the secretion and swelling diminish the silver solution may be weaker and may be applied less frequently. Should the integument of the lids lose some of its epithelium or become roughened, some borated vaselin may be applied after each cleansing of the eyes.

When ulcer of the cornea occurs, atropin in weak solution (gr. ij to ʒj) should be instilled twice daily if the ulcer is central; if marginal, eserin (gr. j to ʒj) may be alternated with the atropin. The treatment may be varied as indicated when considering the treatment of gonorrheal conjunctivitis of adults (page 280).

Croupous Conjunctivitis (*Membranous Conjunctivitis*).—There is a class of cases characterized by a slight swelling of the lids, by a flaky serous discharge, and by the deposit of a fibrinous pseudo-membrane on the surface of the palpebral conjunctiva, extending in some cases on to the ocular conjunctiva, which from a bacteriological or clinical standpoint cannot be included with any other form of conjunctivitis. Graefe¹ terms the disease pseudo-membranous or croupous, in contradistinction to the diphtheritic form. The cases are comparatively rare.

Etiology.—No exact cause is known. The affection is regarded as a mild diphtheria by some authors.

Pathology and Pathological Anatomy.—The conjunctiva is thickened, and shows on section the presence of leukocytes and an increase in nuclei. The epithelial layer is reduced in thickness; blood-vessels are numerous and are enlarged. The pseudo-membrane consists of fibrin, which includes in its meshwork epithelial cells from the conjunctiva, leukocytes, red blood-corpuscles, and various forms of micro-organisms. The pseudo-membranes found in epidemic conjunctivitis, gonorrheal conjunctivitis, diphtheritic conjunctivitis, and those that cover the surface of the conjunctiva after burns with acids, steam, or after scarifying the conjunctiva, differ from each other microscopically only in their bacterial contents and the products of the bacterial growth. Thus membranous conjunctivitis has been ascribed to staphylococci, streptococci, Löffler-bacilli, and diplococci.²

Symptoms.—The symptoms are not severe. The patient complains of obscuration of vision, slight itching, and some burning pain. There is some photophobia. The lids are slightly swollen and somewhat hyperemic. On everting the lids a grayish pseudo-membrane is found. It can be separated from the conjunctiva with comparative ease, but leaves a slightly bleeding surface. The fibrin filaments do not appear to be so numerous or to penetrate so far into the conjunctiva as is the case in diphtheritic conjunctivitis. Removal is followed by rapid regeneration of the membrane, and this tendency may continue for from ten days to many months or even longer.

Diagnosis.—The diagnosis is arrived at largely by exclusion. The sub-acute nature of the disease, the absence of any known specific micro-organism, and the persistence of the affection serve to establish a diagnosis.

Prognosis.—The prognosis is good in perhaps 50 per cent. of the cases. Although the disease persists for a long time, appropriate treatment will often produce a gradual diminution in the tendency to reproduce the membrane and the patient will recover. The cornea remains clear for a long time—ten days or perhaps as many weeks. It may finally become the seat of ulcerative processes and be partly or totally destroyed.

Treatment.—Unfortunately, treatment appears to be of little avail in some cases; in others a tardy response is secured. It appears to be almost useless to remove the membrane. Frequent and prolonged bathing with some mild antiseptic solution, as carbolyzed water, corrosive sublimate (1:10,000), chlorin-water, or a 4 per cent. solution of boric acid, is indicated.

¹ *Archiv f. Ophth.*, 1854, 1 Abth., i. 168.

² For an article on "Pathology of Chronic Membranous Conjunctivitis" by Lucien Howe, consult *Trans. Amer. Ophth. Soc.*, 1897, viii. 36-44.

Some writers believe that it is best to remove the membrane and to treat the surface with the mitigated stick of nitrate of silver; but this measure is of doubtful value. A solution of chlorate of potassium has been suggested, as have also applications of iodoform and quinin.

Diphtheritic Conjunctivitis (*Membranous Conjunctivitis*).—This is a severe, acute affection of the conjunctiva, characterized by intense swelling of the lids, which become thick, hard, and smooth, and by the presence of a pseudo-membrane on the surface of the ocular and palpebral conjunctivæ. It attacks individuals of all ages except the new-born (von Graefe), but is most frequent in children. Both eyes are generally involved.

Etiology.—The direct cause is without doubt a specific micro-organism known as the *diphtheritic* or *Klebs-Löffler-bacillus* (Fig. 190), which develops on the conjunctiva only when that membrane is in a suitable condition to receive it. A depreciation of the resisting power of the conjunctiva to the inroads of bacteria, the result of malnutrition or an acute illness, as scarlet fever or measles, will favor an attack. The affection is more frequent during the climatic changes of fall and spring and when epidemics of diphtheria of the air-passages occur. Many cases accompany and are secondary to faucial and nasal diphtheria, but the disease may occur primarily in the eye. To produce the disease direct infection of the conjunctiva with secretion containing the bacilli is necessary. Von Graefe¹ states that simple conjunctivitis renders the conjunctiva susceptible to the diphtheritic poison.

Pathology and Pathological Anatomy.—A congestion of the blood-vessels of the conjunctiva and lids first occurs, which is soon followed by the transudation of leukocytes and plastic material into the tissue of the lids and on to the surface of the conjunctiva. A partial destruction of the epithelial layer of a portion of the conjunctiva is probably necessary before the plastic exudation can find its way to the surface of the conjunctiva. The circulation is greatly impeded by the presence of the exudation. The pseudo-membrane is composed of layers of fibrin which enclose leukocytes, degenerating epithelial cells, red blood-corpuscles, and various forms of bacteria, prominent among which are the *diphtheritic bacilli*. At the base of the pseudo-membrane fibrillæ of fibrin embrace the superficial epithelial cells

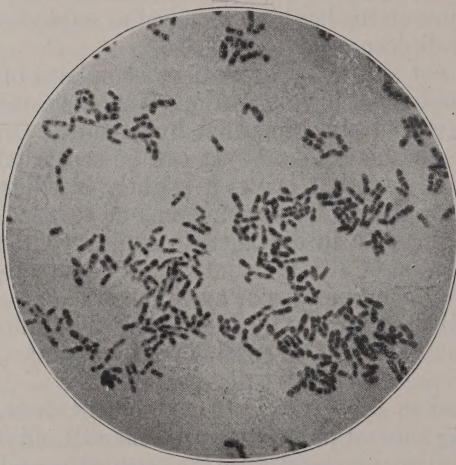


FIG. 190.—*Bacillus diphtheriæ*, from a culture upon blood-serum; $\times 1000$ (Fränkel and Pfeiffer).

and extend between them, causing the membrane to adhere closely during the time of its formation.

Diagnosis.—In some cases it is difficult to discriminate between membranous conjunctivitis due to diphtheria and that due to other forms of inflammation. Caustic applications in mild forms of conjunctivitis in infants and children may produce a pseudo-membrane and an intense plastic infiltration of the lid that may be mistaken for diphtheria. Severe cases of gonorrheal and of epidemic conjunctivitis may assume a diphtheritic aspect.

¹ *Archiv f. Ophth.*, 1854, 1 Abth., p. 168.

The history will aid in eliminating error, but the most conclusive method is that of bacteriological examination. Should the examination of a cover-glass specimen fail to afford positive results, cultivation experiments may be tried.

Symptoms.—In a typical case the onset is sudden. Slight discomfort in the lids, increased lachrymation, and congestion of the conjunctiva precede the severer symptoms by a few hours. Swelling of the lids takes place rapidly: at the end of twenty-four hours the upper lid may have attained four or five times its normal thickness. The folds of the skin of the lid are obliterated; it becomes shiny and assumes a dusky-red hue. The lid is hard to the touch, slightly elastic, closes the eye completely, and cannot be easily raised or everted. A little flaky serous secretion, sometimes tinged with blood, oozes from between the lids at this stage. Attempts to open the eye on the part of the patient are futile, and the surgeon will only partly succeed. A sensation of weight and tension on the globe is experienced, but aside from this there is little pain.

On raising the lid from the globe the palpebral and often the ocular conjunctival surface will be found to be covered with a gray membrane, which, in the average case, is about one millimeter in thickness. On attempts to remove this membrane shortly after it has formed, it will be found to be closely adherent: forcible removal leaves a raw, bleeding surface, which is soon covered again by new-formed membrane.

The acute stage, which may last three to seven days, is accompanied by slight rise of bodily temperature, and sometimes by cephalalgia. Gradually the lids become less rigid, the secretion more puriform; the pseudo-membrane comes away in large or small plaques, and finally disappears. Corneal complications in the form of ulcers and extensive sloughing frequently develop, not only when the membranous deposit is extensive, but also when it is moderate in amount. There is great variation in the degree of severity, rapid destruction of the eye occurring in some cases, while others are so mild that the nature of the disease is not recognized.

Prognosis.—Diphtheritic conjunctivitis is probably the most destructive disease that affects the conjunctiva. The nutrition of the cornea is often interfered with at an early stage, and the membrane sloughs. Of 40 cases reported by von Graefe occurring in children, 9 eyes were destroyed, in 3 there were adherent leukomata, in 7 simple leukomata, and in 21 the cornea remained unaffected. Of 8 cases in adults, 5 sustained perforation of the cornea, and 3 presented marked simple leukomata after the disease had passed. Symblepharon of varying degrees may result from adhesion of opposing raw surfaces. Tendinous cicatricial bands may form in the conjunctiva. Great changes in the lid may ensue as a result of the formation of cicatricial tissue.

Treatment.—The indications are to prevent the communication of the disease to the fellow-eye and to the eyes of other individuals, to limit the infiltration of the lids, to prevent destruction of the cornea by pressure or by infection, and to check the extension of the diphtheritic process to other mucous membranes. Aseptic or antiseptic solutions may be employed to cleanse the unaffected eye at stated intervals, or, better still, Buller's shield may be applied to the sound eye. The patient should be isolated, dressings and secretions from the eye destroyed, and towels, linen, etc. disinfected after use. Cold applications should be made as advised on page 277, until the lids are less tense. A free canthotomy will cause desired depletion and relieve the pressure on the eyeball exerted by the tense lids. The conjunctival sac should be carefully cleansed at frequent intervals with a solution of boric acid, bichlorid of mercury (1 : 5000 or 10,000), or chlorin-water (one-

half the U. S. P. strength). To prevent extension to the mucous membrane of the air-passages mercury to saturation has been advised. The usual constitutional treatment of diphtheria is indicated.

Recently, *serum-therapy* has been resorted to with results which, if uniformly as brilliant as in the cases reported, will rob the disease of its terrors.¹ As soon as the diagnosis is made, 10 cgm. of Behring's diphtheria-antitoxin is injected into the abdominal wall, and the injection is repeated after forty-eight hours if there is not a marked recession of the disease. In many cases improvement is noted before the end of the first twenty-four hours, and the membrane disappears before the expiration of forty-eight hours. Antitoxin is said to modify favorably the necrotic process in the cornea.

Phlyctenular Conjunctivitis (*Lymphatic Conjunctivitis* (Fuchs); *Scrofulous Ophthalmia*; *Eczema of the Conjunctiva*).—This disease is characterized by the appearance of one or more small translucent elevations at the limbus or at some point on the ocular conjunctiva, accompanied by an increased local vascularization (Fig. 191). If a single nodule appears, it is situated at the

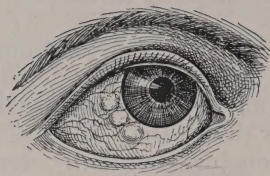


FIG. 191.—Phlyctenular conjunctivitis (De Schweinitz).

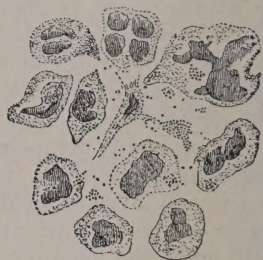


FIG. 192.—Pus with staphylococci; $\times$ 800 (Flügge).

apex of a triangular patch of injected vessels, the base of the triangle being directed toward the equator of the globe. The affection is common in children, never affects the new-born, and is rarely seen in adults.

Etiology.—A depraved condition of the system induced by inherited taints, malnutrition, filth, and bad hygienic surroundings predisposes to this affection. Although most frequently met with among the children of the poor, the children of the rich are not exempt. Experiments that have been conducted with cultivations made from the contents of the vesicles permit of but little doubt that the immediate cause is the presence of the *staphylococcus pyogenes aureus* or *albus* beneath the epithelium of the affected portion of the conjunctiva (see Fig. 192). This affection is frequently associated with moist eczema of the lids, face, scalp, ears, or other parts. The nodules of eczema closely resemble those of phlyctenular conjunctivitis, from which the same micro-organism may be cultivated. It is undoubtedly from the eczematous process that the infectious principle is derived in many cases.

Pustular blepharitis marginalis supplies the necessary bacterium in some cases. Phlyctenular conjunctivitis frequently follows the exanthemata, as measles and scarlet fever. Simple and epidemic catarrh of the conjunctiva encourage to the development of phlyctenulæ, which appear six or seven days after the onset of the acute conjunctivitis due to a secondary infection. Nasopharyngeal disease always accompanies the affection.

¹ Hamilton and Jones: *Brit. Med. Journ.*, 1895, p. 1419; Morax: *Annal. d'Oculistique*, cxiii. p. 360; Coppez: *Revue gén. d'Ophthal.*, Feb., 1896, p. 51; Standish: *Trans. Amer. Ophth. Soc.*, 1897, viii. 44-50.

Pathology.—Apparently as a result of the depreciation of the resisting powers of the tissues of the body, the surface cells do not prevent the entrance and development of the pathogenic micro-organisms. The contents of the nodule in the early stage is a thickened fluid containing many leukocytes and some granules; later the contents resemble pus. A section of a nodule shows it to be formed by the elevation of the epithelial layer from the underlying basement-membrane; the vessels in the vicinity are congested, and there is an increased number of leukocytes in the adjacent tissue.

Symptoms.—The palpebral conjunctiva is congested; this is also the condition of the ocular conjunctiva in the affected portion. There are slight stinging pain, lachrymation, photophobia, and annoyance on use of the eyes. The photophobia in phlyctenular conjunctivitis is slight compared with that accompanying *phlyctenular keratitis* (see page 305). In almost all cases the preauricular glands are enlarged. Frequently there is marked coryza, the upper lip becoming thickened by the flow of irritating secretions over it.

Diagnosis.—Herpes conjunctivæ, vernal catarrh, and trachoma affecting the ocular conjunctiva may be mistaken for phlyctenular conjunctivitis. In herpes the vesicles which spring from the injected conjunctiva are transparent and appear in clusters. They do not select the limbus, and are much more transient. In vernal catarrh the elevations are larger and do not ulcerate. Trachoma of the ocular conjunctiva is associated with trachoma of the palpebral conjunctiva, and seldom affects the limbus conjunctivæ.

Prognosis.—When the conjunctiva only is affected the prognosis is favorable, as recovery occurs without leaving a trace of the disease. The duration is variable, from a few days to a number of months, successive phlyctenulæ appearing. Recurrences are frequently observed.

Treatment.—This should be local and constitutional. The local treatment consists in keeping the eyes clean by the use of some antiseptic lotion. Bathing with a saturated solution of boric acid in water three or four times a day gives good results. An ointment of the yellow oxid of mercury (1–1.5 per cent.), introduced into the conjunctival sac twice daily after the phlyctenule has broken down, is of much value. Calomel may be dusted on the conjunctiva once daily if the patient is not taking iodine. A mild alterative in the shape of small doses of calomel may be continued for some weeks with benefit. Nourishing food and general tonic treatment—iron, quinin, cod-liver oil, and perhaps strychnin—may be given. The naso-pharynx should receive appropriate treatment. (Consult also *Phlyctenular Keratoconjunctivitis*, page 307.)

Herpes Conjunctivæ.—This occurs at times in connection with herpes febrilis or herpes zoster affecting the lids and face. It is seldom that the complete vesicles are found, as they rupture early, and their site is marked by shreds of epithelium which remain attached to the conjunctiva at the margins of the preceding vesicles.

The condition is accompanied by irritation and increased lachrymation. Herpes of the cornea may accompany herpes conjunctivæ. The affection is extremely rare. It calls for no treatment other than that given for the affection which it accompanies (see also page 309).

Vernal Conjunctivitis or Catarrh (*Fruehjahr's Catarrh* (Saemisch); *Spring Catarrh*; *Phlyctena Pallida* (Hirschberg)).—This is a chronic form of conjunctivitis which presents peculiar features. The tarsal conjunctiva is covered by small, closely-placed, flattened, papilliform excrescences, which appear to be covered by a delicate grayish film. At the margin of the cornea the conjunctiva is thickened and unequally raised, forming pale, translucent,

or waxy nodules, which are largest opposite the palpebral fissure, encroach a little on the cornea, but extend to a greater distance outward into the ocular conjunctiva.

Etiology.—Nothing definite is known of the cause of the affection. Some writers believe it to be a form of trachoma, and so classify it. Fuchs is of the opinion that it is a specific disease, and that, although no specific micro-organism has been discovered, it is produced by such a micro-organism. Both eyes are affected. The male sex suffers most, the attacks being experienced between the ages of one and thirty-five years.

Pathology.—Little is known regarding the development of the papillæ of the tarsal conjunctiva. The elevations about the cornea are preceded by local injection of the vessels; the thickening develops slowly. The papillæ of the tarsal conjunctiva are composed of a central cylinder or cone, made up of connective tissue and a few small blood-vessels, which is covered by a thickened layer of epithelium. Over the nodules, at the limbus, the epithelial layer is uneven, and is thicker than normal.

Symptoms.—The ropy nature of the secretion produces a sensation as of a foreign body in the eye. There are photophobia, burning of the lids, and blurring of vision, principally due to the presence of secretion on the cornea. Use of the eyes by artificial light increases the irritation and lachrymation; the redness of the ocular conjunctiva about the cornea and the nodules at the limbus are apparent on inspection. On everting the lid the fine fissures of the tarsal conjunctiva due to separation of the papillæ are recognized. The disease gives but little annoyance during winter months, but is very troublesome during the summer months, at which time there is more or less stringy discharge and the eyes are painful. When cold weather comes on the elevations at the margin of the cornea become much smaller, some disappearing entirely; the tarsal conjunctiva is less thickened, but the papilliform elevations still remain. Burnett states that in the colored race the bases of the nodules are pigmented.

Diagnosis.—The history of the case is of great value in making a diagnosis. No other form of conjunctivitis recurs and persists to the same extent during the warm weather. The conjunctivitis that accompanies *hay fever* has none of the anatomical and few of the symptomatic characteristics of this disease.

Vernal catarrh may be confounded with trachoma and with phlyctenular conjunctivitis. The elevations on the tarsal conjunctiva do not have the appearance of the follicles of trachoma, nor do they have the same anatomical structure. The pericorneal elevations differ from those of phlyctenular conjunctivitis in that they are not so transient and do not break down and form ulcers.

Prognosis.—The disease recurs for a number of years, and may then disappear entirely. In the greater number of cases no injury is done to the central area of the cornea; however, the nodules may advance for a considerable distance, and in rare cases may cover the cornea, abolishing useful vision.

Treatment.—A complete cure by means of treatment must not be expected, but much can be done to relieve distressing symptoms, and the advance of the nodules on to the cornea may be checked. Bathing the eyes with a warm solution of boric acid three times daily will serve to keep them fairly clear of secretion. This, with the application of a smooth ointment of the yellow oxid of mercury ($1\frac{1}{2}$ per cent.) to the conjunctival sac twice daily, will produce very favorable results. Calomel and solutions of bichlorid of mercury

are useful. If the nodules are large, they may be reduced and their advance checked by destroying them with the cautery; electrolysis has been recommended. Randolph advises salicylic acid applied to the conjunctiva in the form of an ointment (gr. iiij-3iv) and as a collyrium (gr. v-f 3j).

Follicular Conjunctivitis (*Conjunctivitis Follicularis Simplex*).—This inflammation of the conjunctiva is characterized by the occurrence of small, oval, pale or light-red elevations in the transition folds of the conjunctiva. A few follicles the size of a pinhead are often observed in the tarsal conjunctiva.

Etiology.—Follicular conjunctivitis occurs among persons inhabiting crowded quarters and among those whose habits and surroundings are not cleanly. Soelberg Wells states that he thinks that there can be no doubt that the disease is contagious. It is often met with in the young, and is of frequent occurrence in inmates of residential schools.

Pathology.—The follicles are due, according to Krause and Schmidt, to an abnormal enlargement of the lymphatic follicles of Krause, which are not visible to the unaided eye in the normal state, but which are situated immediately beneath the epithelium of the conjunctiva. They are supposed to be neoplastic growths. The follicles are composed of a mass of lymphoid cells contained in a delicate network of connective tissue having an incomplete capsule in which a few small vessels ramify.

Symptoms.—These are few and not pronounced; indeed, follicular conjunctivitis may exist for months without the knowledge of the individual affected. On inspection the lower lid appears to be slightly thickened; there may be increased lachrymation, some mucoid secretion, and the ocular conjunctiva may be injected. On everting the lower lid the transition fold is found to be reddened, and may be swollen to such an extent that the follicles will not be visible; however, in the greater number of cases the follicles appear as small, oval, translucent nodules, arranged in rows, lying in the transition fold. They may be few or numerous. Although ordinarily confined to the lower, they may be found in large numbers in the upper, transition fold.

Diagnosis and Prognosis.—If the conjunctiva is not greatly swollen, the diagnosis is easy. Follicular conjunctivitis differs from typical trachoma in that it is more transient, is more amenable to treatment, and is not followed by cicatricial changes. The *prognosis* is favorable for a return to the normal condition of health in a number of months if medicinal measures are adopted, and in two or three weeks if surgical measures are employed. There is no tendency to involvement of the cornea.

Treatment.—The patient should not be allowed to use the same bathing appliances with others, and should be isolated when practicable. The hygienic conditions should be made as good as possible, and cleanliness should be insisted upon. Constitutional treatment in the form of tonics, iron, strychnin, or quinin should be employed. Locally, a mild astringent collyrium of zinc sulphate (gr. j to 3j), alum (gr. j to 3j), tannic acid, and glycerin (gr. 30-60 to 3j) may be employed. The sulphate of copper or alum-crystal may be lightly applied to the follicles every forty-eight hours.

For the *surgical treatment* of this affection see Surgical Treatment for Trachoma, page 563. Expression of the follicles with suitable forceps is the most efficient measure to destroy them.

Granular Conjunctivitis (*Trachoma; Granular Ophthalmia; Military Ophthalmia*).—This disease of the conjunctiva presents as its distinctive feature in its early or first stage numerous discrete, oval bodies in the tarsal

conjunctiva and transition fold (*trachoma bodies*). When the conjunctiva is not hypertrophied these granules are prominent, translucent, and resemble frog-spawn, to which they have been compared. Granular conjunctivitis is most common in youth; however, individuals at all ages are affected, except perhaps those in the first year of life.

Description.—In describing the clinical features of granular conjunctivitis it is convenient to divide it into three stages.

The *first stage* is that in which the granulations are discrete, in which the cicatricial contraction has not occurred, and may be termed the stage of hypertrophy. It manifests itself in a number of distinct phases which we will consider separately.

1. Cases appear sporadically in which, with little or no previous indication, no secretion, but with perhaps a little thickening of the lids, the granules develop, and the physician is surprised on everting the lid to find the palpebral conjunctiva completely studded with well-formed granulations (Fig. 193). There is scarcely any injection of the conjunctiva and no marked discomfort to the individual. Only one member of a family may be affected or only one or two pupils in a school may show this condition. If this form of granular conjunctivitis is at all contagious, it is only very slightly so, probably because of the very scanty secretion.

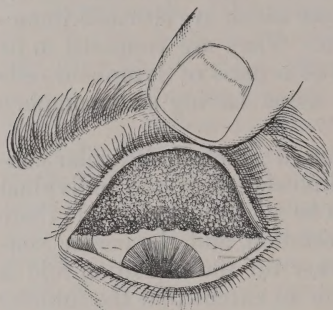


FIG. 193.—Follicular trachoma (Johnson).

2. The clinical picture presented by this phase of the disease is the most common. The onset is not very *acute*, but there is redness of the conjunctiva and of the margins of the lids, accompanied by increased lachrymation, scanty mucoid secretion, and a sensation of burning and itching. In the morning the

lids are stuck together, but can be opened without much difficulty. At the end of a week the conjunctiva at the transition folds is thickened, injected, and presents a few shreds of mucoid secretion in its folds. The pain and irritation have increased. There may be some photophobia. The irritation is aggravated by use of the eyes.

At the end of two weeks, if the hypertrophy of the conjunctiva is not too great, numerous slight elevations which have much the color of the conjunctiva, can be made out, situated in the transition folds and frequently in the tarsal conjunctiva. The conjunctiva is much hypertrophied, and in a small percentage of the cases the granules are so hidden that they are seen only when the hypertrophy subsides. In from three to six weeks the hypertrophied condition of the conjunctiva lessens; a hyperemic condition prevails and becomes chronic. The cases are contagious from the time that the secretion appears until it disappears. The disease often appears in epidemic form. Corneal complications may occur during the second stage, and are not uncommon.

3. The third form of onset is, so far as the writer knows, confined to adults, and begins much the same as an acute conjunctivitis of not a very severe type. The eyelids are considerably swollen; the secretion, which is muco-purulent, is accompanied by much lachrymation; the *hypertrophy of the conjunctiva* is excessive, causing it to lie in large folds in the upper and lower cul-de-sacs. The ocular conjunctiva is injected, but not much hypertrophied; the caruncle and semilunar fold frequently take part in the general

thickening. None of the ordinary forms of treatment have much effect in reducing the hypertrophy, and at the end of two to four weeks it becomes evident that the large rigid folds represent one mass of lymphoid or trachomatous tissue.

Corneal irritation is experienced relatively soon in this form of the disease, and quite marked *pannus* may also occur early. This variety is eminently contagious, the type produced corresponding with this or with the second described.

The first stage of granular conjunctivitis, as described in the three types of onset, merges gradually into the *second stage*, which is one of *commencing atrophy* with the persistence of granulation tissue.

The hypertrophy of the conjunctival tissue has passed away, and bands of cicatricial tissue begin to appear (Fig. 194). The individual follicles have lost their character and have coalesced, forming larger or smaller masses; not infrequently the upper tarsus of the upper lid is one continuous plaque of lymphoid tissue. The area of the conjunctiva is considerably lessened by cicatricial contraction. The tarsus is not so wide, and is more sharply curved from above downward. The margins of the lids are thickened, the palpebral fissure narrowed (partial ptosis) and shortened. Lymphoid tissue may appear on the ocular conjunctiva or even on the cornea.

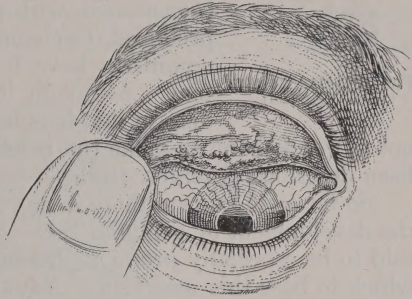


FIG. 194.—Typical granular lid and beginning cicatrization, with pannus (Berry).

From irritation by the rubbing of the roughened lids the corneal epithelium is disturbed, and in the effort on the part of nature to protect this membrane *vascular pannus* appears over the parts most seriously menaced (Fig. 194). When the corneal epithelium is disturbed and *superficial ulcers* are established, the irritation to the eye when exposed to light is intense, and marked photophobia is experienced. This brings on contraction of the orbicularis palpebrarum muscle and clonic or tonic spasms, with a forward bending of the head.

With a cicatricial contraction of the inner or posterior surface of the tarsus, which increases the curvature and thickens its lower half, and the forcing down of the marginal fibers of the orbicularis palpebrarum muscle, the eyelashes are made to impinge upon the cornea and *entropion* is established. Slight mucoid secretion and profuse lachrymation accompany this stage; frequently the tears and secretion flow on to the cheeks, causing more or less erosion of the epithelium of the lower lid and face.

The *third stage* is essentially one of atrophy. All lymphoid tissue has disappeared, the cicatricial contraction has partly or wholly abolished the retrotarsal folds, and the conjunctival sacs are rendered very shallow. There may remain some islets of fairly good conjunctiva and sufficient moisture to lubricate the lids. The cornea is partly or wholly opaque. In some cases the eye becomes opaque and dry (*xerosis*). Vision is greatly impaired or wholly abolished.

Although granular conjunctivitis in not a few cases pursues the course outlined above, it may also assume a much more benign type.

Duration.—There is great variation in the duration of all the stages of granular conjunctivitis. The first stage may give way to the second stage in

the course of three or four months; it may last six months or a year. The second stage is much more prolonged; it may never pass into the third stage. Seldom fewer than ten years are required to bring the patient to the stage of atrophy, and in most cases the individual has reached middle age before complete atrophy is established.

Etiology.—Bad air, overcrowding, poor and scanty food, and filth contribute largely to the development of granular conjunctivitis. It is very probable that a contagium must be added to produce the disease. It becomes epidemic in residential schools, barracks, almshouses, prisons, etc.

A micro-organism supposed to be specific has been described by Sattler and Michel. It is a small double coccus, and may be cultivated from the contents of a trachoma follicle (see Fig. 195). No satisfactory results have been reached by inoculation-experiments. Mutermilch¹ has described a fungus which he terms *microsporion trachomatosum*, with pure cultures of which he claims to have produced trachoma in calves and rabbits. Other micro-organisms have been mentioned as probable causative factors. Although it is thought by all who have studied the disease that it is microphytic in origin, sufficient evidence is not as yet at hand to make the belief indisputable. Parasitic protozoa have been described (Pfeiffer, Ridley).



FIG. 195.—Trachoma coccus (Michel).

So far as is known, there is no constitutional condition that predisposes to the development of granular lids. Individuals of a lymphatic condition are said to be especially prone to trachoma, but there is no good evidence upon which to base this assertion. Among certain peoples, as the Jews, Italians, Egyptians, and other inhabitants of the East, trachoma is prevalent. According to Burnett, the negro of pure blood is immune to trachoma; but his observations have apparently been confined to the negroes of our Southern States. The geographical distribution of granular lids has attracted much attention. In certain regions of the inhabited portions of the earth the disease is of extremely rare occurrence. This is true of the Scandinavian peninsula and of the southern part of California.

Pathology and Pathological Anatomy.—In the inflammatory cases the blood-vessels become enlarged, and apparently increase in number, accompanied by an increase in the nuclei and in the cellular elements of the conjunctiva. The papillary body becomes enlarged, the lymphoid tissue is greatly increased, and numerous small lymphoid follicles develop in the palpebral conjunctiva.

An attempt has been made to separate *folliculosis* from trachoma on histological grounds, the claim being made that in folliculosis there is an enlargement of the lymph-follicles of Krause, which normally reside in the conjunctiva. It is affirmed that the follicles in granular conjunctivitis are neoplasms, and, although anatomically identical with the follicles in folliculosis, have no connection with it. In careful studies made by the writer no such distinction has appeared to be possible. The follicle consists of aggregations of lymph-corpuscles situated immediately beneath the epithelium, having a more or less marked fibro-vascular capsule and traversed by very fine trabeculae of connective-tissue fibers; some capillaries may be traced into them. The epithelium over the follicle is irregular and slightly thickened in some parts. After the granules have coalesced the mass resembles a flattened lymphoma (Fig. 196).

The cicatricial tissue is made up of fine connective-tissue fibrillae closely

¹ *Annal. d'Oculistique*, Oct., 1891–May, 1892.

associated, which contract as they mature. Small *cysts* develop in the conjunctiva in the second stage in some cases of granular conjunctivitis.

Diagnosis.—Granular conjunctivitis may be confounded with the papilliform swellings of the transition fold which occur in acute muco-purulent and in purulent conjunctivitis, with vernal catarrh, and with the cases of fibroid or fungoid excrescences of the conjunctiva.

In the first a further observation of the case will serve to decide its nature. Vernal catarrh affords by its history, by the fact that the transition folds are relatively free, and by the peculiar character and arrangement of the elevations about the cornea sufficient data to relegate it to another class. *Fibrous* or *horny granulations* may require careful study—microscopically perhaps—to enable one who has not observed other cases to determine their nature. The masses are not *lymphomata*, but are *fibromata* with a much-thickened epithelial layer.

Prognosis.—This is favorable if the case is seen before much permanent impairment of vision has resulted. If seen in the first stage, a cure may be

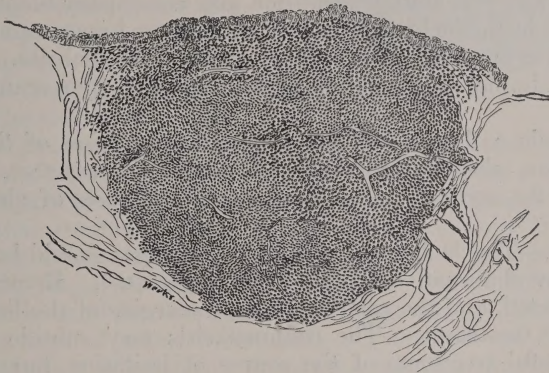


FIG. 196.—Section of a trachoma follicle, showing an ill-defined capsule containing vessels, small blood-vessels in the body of the follicle, and the immediate proximity of the epithelial cells to the lymphoid cells of the follicle (camera lucida).

effected with but little damage to any of the tissue involved. Some cicatricial tissue will develop in the conjunctiva at the site of the follicles, but the function of the eye will be but little interfered with.

In the second stage much can be done to improve the condition if treatment is instituted. If the disease is permitted to take its course, spontaneous recovery will occur in some cases, but in many *corneal ulcer*, *pannus*, *trichiasis*, and *entropion* will develop.

When the third stage is reached little can be done to improve the condition of the eye.

Treatment.—This is prophylactic, medicinal, and surgical.

Isolation should be practised, if possible, so long as discharge persists. Cleanliness by irrigating the eye with some bland, antiseptic, or mild germicidal solution is first to be observed, care being taken that bathing appliances used by the patient shall not be used by others. A solution of boric acid or a solution of bichlorid of mercury (1:10,000 or 1:15,000) or formalin (1:3000) may be employed three or four times daily, bathing ten or twenty minutes each time. A solution of bichlorid of mercury (1:5000 or 1:8000) which contains a few grains of sodium chlorid, or chlorin-water, 50 per cent., officinal, may be dropped freely into the eye after each bathing. Applications

of nitrate of silver (gr. iij to ʒj) once daily will be of much value if there is secretion.

When the acute symptoms have subsided stimulating astringent application may be made. Alum-crystal, sulphate-of-copper crystal, or the mitigated stick of nitrate of silver may be employed to lightly touch the granulations once every second day. Sulphate of copper is most generally used and gives greatest satisfaction. Not all conjunctivæ will tolerate these applications; trial will enable one to decide in which cases to employ them. In the intervals between the applications the patient should continue with the bathing and drops, using them at least three times daily. Corneal complications usually require atropin, but nothing additional. With an improvement in the lids the corneal ulcers will disappear.

Surgical treatment is of the greatest value in the early stage, and is described on page 563.

Chronic Conjunctivitis (*Chronic Ophthalmia*).—A thickened, congested, irritable condition of the palpebral conjunctiva sometimes persists for months after an acute conjunctivitis, accompanied by redness of the margins of the lids. A similar condition may accompany blepharitis marginalis, concretions in the lachrymal canals, atrophic or hypertrophic rhinitis, and eye-strain from errors of refraction or muscular abnormalities. The affection is more than a simple congestion, being accompanied by a scanty muco-purulent secretion.

In old people a flabby, slightly congested condition of the conjunctiva sometimes exists, also accompanied by a scanty discharge. Swelling or *hypertrophy of the caruncle* is found in almost all cases of chronic conjunctivitis.

Treatment.—The lachrymal and nasal passages should be carefully examined and any abnormal condition properly treated. Errors of refraction should be corrected, and the condition of the margins of the lids made favorable by proper treatment. The conjunctivitis may subside spontaneously after the successful treatment of the source of irritation, but in many cases stimulating and astringent measures must be resorted to. Applications may be made with a solution of nitrate of silver (1 per cent.) once in forty-eight hours until the secretion ceases, or with glycerol of tannin (ʒss to ʒij) sprayed on the conjunctiva once daily. Extremely light applications of sulphate of copper or alum-crystal may be made every second day. These measures, with careful cleansing two or three times daily with a solution of boric acid (3 per cent.), will in many cases effect a cure.

Egyptian and Military Ophthalmia.—These terms are used without discrimination to indicate acute or subacute inflammations of the conjunctiva which appear in Egypt or may affect an army. They comprise at least three distinct forms—namely, epidemic acute contagious conjunctivitis, gonorrheal conjunctivitis,¹ and acute trachoma. The consideration of these diseases is found under their appropriate headings.

Lachrymal conjunctivitis is an inflammation of the conjunctiva accompanying dacryocystitis, and due to the presence of the irritating purulent secretion from the lachrymal sac, which contains *streptococci* (Fig. 197). The inner third of the palpebral and ocular conjunctiva is most congested, but the whole lower cul-de-sac is frequently involved. The eye is often suffused with tears and muco-purulent secretions, which, failing to escape by the tear-passages, flow over on to the cheek.

The presence of a dacryocystitis determines the *diagnosis*. It is easy,

¹ Koch: *Weiner med. Woch.*, 1883, 1550.

however, to overlook this cause, and it is therefore advisable to examine the condition of the lachrymal sac in all cases of conjunctivitis.

The *prognosis* is favorable if the dacryocystitis can be corrected. In some cases an ulcer of the cornea forms, becomes infected, and perforation follows, with greater or less impairment of vision.

An early correction of the dacryocystitis is advisable in all cases.

Lithiasis conjunctivæ is characterized by the formation of white calcareous concretions in the acini of the Meibomian glands. These concretions penetrate the epithelial layer and produce great irritation by friction on the cornea and conjunctiva. They usually accompany a gouty diathesis, and are apparently of the nature of tophi.

On everting the lids the white concretions are readily seen and recognized. The *prognosis* is good; however, new formations of similar deposits must be expected. The *treatment* consists of liberation of the concretions by incision.

Toxic conjunctivitis is a term employed to designate those forms of conjunctivitis that are due to the chemical action of certain substances. The following substances may be mentioned as acting in this manner: Atropin and other mydriatics, the myotics, chrysarobin, calomel, the dust from anilin dyes, fumes from menthol and formalin, and virus introduced by the bites of insects.

The conjunctivæ of some individuals do not tolerate atropin even in very weak solutions. When a few drops of a solution of atropin are introduced into the conjunctival sac of such individuals, a smarting and pricking sensation is soon experienced; the conjunctiva and lids become slightly swollen and congested. The congestion of the lid is confined to the palpebral portion, imparting a peculiar and quite characteristic appearance. More or less dryness of the throat and irritation of the nasal mucous membrane may accompany the conjunctivitis. If no more atropin is instilled, the smarting and swelling subside in twenty-four to forty-eight hours, and recovery ensues. A similar condition may follow the use of hyoscyamin, duboisin, cocain, and homatropin, but is much less apt to occur. Eserin sometimes produces congestion of the conjunctiva. If a non-sterile solution of atropin be used daily for some time, a follicular conjunctivitis, in which the follicles are largely confined to the lower cul-de-sac, may be produced. The condition responds readily to treatment after the atropin is discontinued.

Chrysarobin, when used in the form of an ointment, may produce a violent non-suppurative conjunctivitis which gradually subsides on the discontinuance of the drug.

Calomel when dusted into the eye, as in the treatment of corneal affections in one who is taking iodine in any form, undergoes a rapid change into an iodide through the action of the lachrymal fluid, and may produce marked inflammation of the conjunctiva with superficial ulcers (*calomel conjunctivitis*). If the calomel treatment is withdrawn and the conjunctival sac thoroughly cleansed, recovery will rapidly occur.

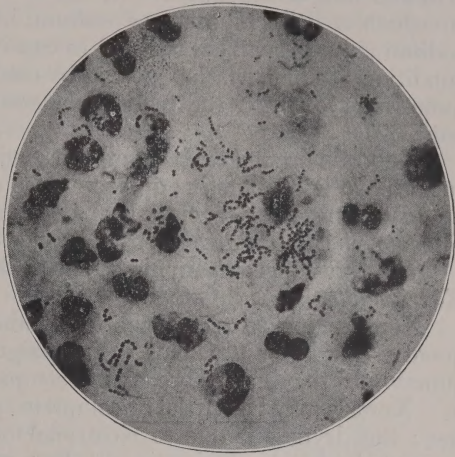


FIG. 197.—Streptococci pyogenes (Fraenkel and Pfeiffer).

The irritation occasioned by the dust from anilin dyes and the fumes from menthol and formalin will subside when the cause is removed.

The sting of the fly produces intense edematous swelling of the conjunctiva and lids, accompanied with but little secretion. Bathing with hot water to which a little baborate of sodium, bicarbonate of sodium, boric acid, or sodium chlorid is added will aid in causing the tissues to resume their normal condition. The irritation caused by caterpillar hairs produces a form of conjunctivitis to which the name *ophthalmia nodosa* has been applied (see also page 327).

Xerosis (*xerophthalmos*) of the conjunctiva is a condition in which the surface of the conjunctiva appears to be dry. Two forms are recognized:

(a) Xerosis due to cicatricial degeneration of the conjunctiva (*X. parenchymatosa*, *essential atrophy of the conjunctiva*).

(b) Xerosis accompanying a general disease (*X. superficialis*, *X. epithelialis*, *X. triangularis*, *X. infantilis*).

Xerosis due to cicatricial degeneration of the conjunctiva is most frequently caused by trachoma. Pemphigus, burns, and exposure of the conjunctiva to the atmosphere, as in ectropion and lagophthalmos, may produce it. Xerosis may be partial or complete. In xerosis the conjunctiva is lusterless; the dryness is due to cicatricial obliteration of secreting tissues in or connected with the conjunctiva. This affection is seldom met with in individuals who have not reached mature years. It is incurable.

Xerosis due to general disease appears both in a mild and in a severe form. The mild form is characterized by the appearance of triangular masses of a foamy, lardaceous secretion, not moistened by the tears, which are located at the margins of the cornea in the horizontal meridian. The bases of the triangles are placed next to the cornea. *Nyctalopia* (night-blindness) accompanies this condition. It appears in children and adults, and is the result of malnutrition. Inmates of prisons, soldiers in barracks or field, railroad laborers, sailors on long voyages, and those who eat a poor quality of food with but little variety for long periods of time, suffer from this affection.

A severer form, which attacks infants and very young children only, is often associated with *kerato-malacia* (see page 318). The disease extends from the conjunctiva to the cornea, producing complete destruction of that membrane. The secretion, which is of the same nature as that which appears in the mild form, first develops in the conjunctival sac and extends over the eye.

Prognosis.—The prognosis in the mild form is favorable. Infants and young children suffering from the severe form seldom recover.

Microscopical examination of the secretion in these cases discloses the presence in almost pure culture of a plump, short bacillus, which usually appears in pairs. This bacillus has been fully described by Leber, and was thought by him to be the pathogenic factor in the disease. Other observers have not been able to support this view.

Treatment.—Improvement in the nutrition of the individual is the essential measure to promote recovery.

Amyloid Disease of the Conjunctiva.—This disease is rarely met with in the United States. It is characterized by the appearance of yellowish, waxy, translucent masses in the conjunctival sac, taking their origin most frequently from the retrotarsal fold. The entire conjunctiva may participate in the change, the great thickening converting it into large folds which may overlap the cornea and seriously obstruct vision. The tissue is very friable and is almost devoid of blood-vessels.

Pathology.—The tissue is largely made up of lymphoid cells which in certain places, notably near the surface, have lost their distinctive characteristics and have undergone a hyalin degeneration, contributing to the formation of a homogeneous mass. The hyalin stage passes into an amyloid stage (Raehlmann), when fresh sections give the starch-reaction in the presence of the iodine test. Sarcomatous tissue may be an element in these growths,¹ and osseous deposits may occur in the mass.

The *diagnosis* is easy, no other growth possessing the same appearance, and the *prognosis* is favorable if no malignant element is present. The development is slow. The treatment should consist of thorough removal of the diseased tissue.²

Pterygium is a peculiar fleshy mass of hypertrophied conjunctiva which develops most frequently at the inner, but occasionally at the outer, side of the eyeball. It is wedge-shaped, the base lying at the caruncle; its upper and lower borders overlap the conjunctiva, permitting of the introduction of a probe. The apex of the pterygium advances on to the cornea in the horizontal meridian, rarely passing the center of the pupil (Fig. 198). Pterygia are most frequently met with in men, and are peculiar to adult life.

Etiology.—Irritating particles that pass the margins of the lids and impinge upon the ocular conjunctiva first produce pingueculæ (Fuchs), and later pterygia. Miners, stone-masons, laborers, and those who inhabit countries where there is much alkali dust present the condition most frequently.

A form of pterygium known as *pseudo-ptyergium* is also recognized. This is an irregular growth which may encroach upon the cornea from any direction. It follows burns, ulcerative processes, and injuries to the margin of the cornea.

Pathology.—A transverse section through the body of a pterygium shows it to be composed of loose connective tissue, rich in blood-vessels, and with more or less small-cell infiltration according to the degree of irritation. The epithelial layer is thickened. The tissue of the preceding pinguecula is embodied in that of the pterygium. At the apex of the pterygium an infiltration of small cells is found which extends for a short distance into the superficial lamellæ of the cornea. A very few fine blood-vessels also precede the advance of the growth. Micro-organisms find suitable lodgement in the folds of the tissue of the pterygium.

Pain is experienced only when the pterygium becomes inflamed. Disturbances of vision result from acquired *astigmatism* and from invasion of the pupillary area. The condition can scarcely be confounded with any other disease. If early operation is resorted to, the *prognosis* is good, but recurrence is not uncommon. After the pupillary area is invaded slight nebulous opacities and irregular astigmatism are present after the pterygium is removed.

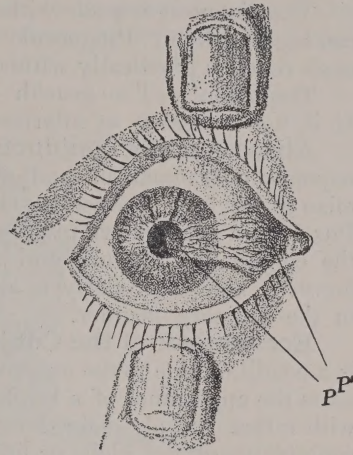


FIG. 198.—Pterygium: P, apex; P', base (Michel).

¹ Prout and Bull: *Archives of Ophthalmology*, vol. viii. p. 73.

² Leber has described a recurring and spreading form of conjunctival disease, characterized by the appearance of raised whitish patches, in the center of which is found a deposit of lime, to which he gives the name *conjunctivitis petrificans*.

Treatment.—This is always surgical—divulsion, excision, or transplantation. Early operation is advised. (See page 561 for technique.)

Pinguecula.—This is a small yellowish elevation in the ocular conjunctiva, situated near the inner margin of the cornea in the horizontal meridian; the growth may also occur near the outer margin of the cornea. Fuchs is of the opinion that pinguecula should be regarded as the early stage of pterygium.

The condition is apparently due to irritation produced by the presence on the ocular conjunctiva of particles of dust and small foreign bodies, and is most frequently observed in those whose occupation brings them in contact with much dust. Formerly supposed to owe its yellow color to the presence of fat-cells, it is now known to be a hyperplasia of the white and elastic connective-tissue fibers of the conjunctiva, together with a colloid substance. Its epithelial layer is considerably thickened.

The diagnosis is made without difficulty, as there is nothing for which it can be mistaken. Pinguecula may degenerate into pterygium, but in many cases remains practically without change.

Treatment.—The growth may be excised or destroyed by the cautery. It is not necessary to interfere in ordinary cases.

Abscess of the conjunctiva is an extremely rare condition. As a consequence of traumatism small abscesses may develop. A suppurating Meibomian gland may produce an abscess that opens on the conjunctival surface. Pus from a suppurative process, taking place in the orbital tissue, may bulge the conjunctiva forward and form a fluctuating tumor. These conditions, however, belong properly to other tissues. The abscess should be opened in the ordinary manner.

Ecchymosis of the Conjunctiva (*Subconjunctival Hemorrhage*).—This is a condition due to the exudation of blood beneath the conjunctiva, and presents the appearance of a bright-red or dark-red spot of varying dimensions with rather sharply-defined margins. The ecchymosis may affect the loose conjunctiva of the globe or lids. The conjunctiva tarsi, because of its close connection with the tarsus, does not permit the blood to pass beneath it.

Etiology and Pathology.—The ecchymosis may be *traumatic* in origin, following squint or other operations, blows, the entrance of a foreign body, or it may be due to the spontaneous rupture of a small subconjunctival blood-vessel (see also page 360). The *spontaneous* exudation of blood usually occurs in elderly individuals, in whom the walls of blood-vessels are undoubtedly weakened by atheromatous processes and give way, and may indicate nephritis, but is sometimes seen in children as a result of violent coughing, vomiting, etc. In certain cases of fracture of the skull through the orbit conjunctival ecchymosis occurs in the outer lower quadrant of the ocular conjunctiva. Very small ecchymotic spots accompany acute forms of conjunctivitis. The blood gradually becomes absorbed and the natural color of the tissues is restored.

Treatment.—Left to itself, the blood will be gradually absorbed. Absorption may be hastened by bathing the eye with water, at as high a temperature as the individual can bear, three or four times daily, for twenty or thirty minutes each time.

Chemosis of the conjunctiva may be active (*inflammatory*) or passive (*non-inflammatory*). It is a condition in which the ocular conjunctiva becomes thickened and raised around the margin of the cornea, forming a uniform shallow pit of which the cornea constitutes the floor.

Etiology and Pathology.—Inflammatory chemosis is rarely absent in

purulent conjunctivitis, and often accompanies pronounced keratitis. When the interior of the eye is the seat of an inflammatory process, as in certain forms of iridocyclitis and infection after cataract operations, chemosis is sometimes produced. It may follow the administration of potassium iodid or succeed an attack of urticaria. It is an occasional accompaniment of nephritis.

Passive chemosis is sometimes observed in alcoholic and gouty individuals.

A section of the tissue in inflammatory chemosis presents an intense infiltration of leukocytes into the subconjunctival tissue at the margin of the cornea, some thin-walled, newly-formed blood-vessels, transuded blood, and fibrin (Fig. 199). In the passive variety the leukocytes are very much less numerous, there are no newly-formed blood-vessels, and the condition is more nearly one of simple edema.

The chemosis is so great in some cases that the swollen conjunctiva overhangs the cornea and obstructs the vision; it may even protrude between the lids. There are no other symptoms added to those accompanying the con-

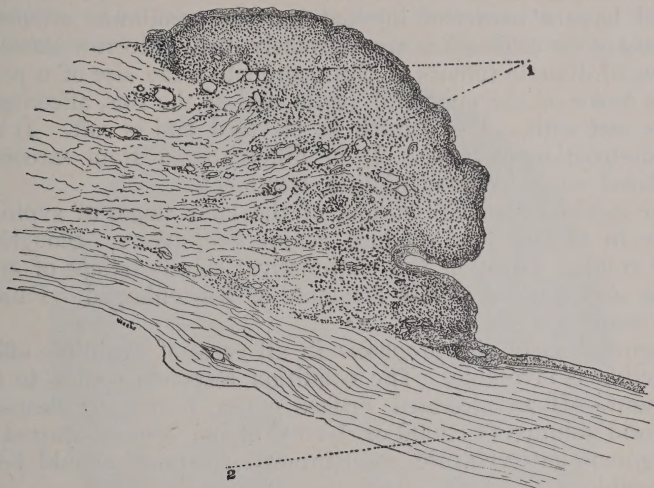


FIG. 199.—Section of the globe, showing chemosis of the conjunctiva (camera lucida). (Extensive small-cell infiltration.) 1, thin-walled blood-vessels; 2, cornea.

dition which has produced the chemosis. The chemosis subsides on subsidence of the accompanying inflammation; if it is intense, scarification may be resorted to.

Emphysema of the Conjunctiva.—Subconjunctival emphysema is characterized by a non-inflammatory lobulated swelling of the conjunctiva, which emits a peculiar fine crackling sound on pressure. It is due to the entrance of air beneath the conjunctiva from injuries to the lids, fracture of the margin of the orbit extending into the frontal sinus, ethmoid sinus, or nasal cavity. The air is absorbed and the condition disappears spontaneously.

Lymphangiectasis conjunctivæ is a benign condition which affects the ocular conjunctiva, and is of much more frequent occurrence in its outer half than in any other part. It consists of a small chain or cluster of vesicles, which vary in size from very minute ones to those the size of a grain of wheat. They are transparent, and are freely movable over the subconjunctival tissue. The cause is not known. The disease is found most frequently in those who suffer from chronic conjunctivitis. The condition is one of dila-

tation of the lymph-channels, the small pockets containing a clear fluid. The diagnosis is not difficult, as there is nothing else with which it may be confounded. The vesicles may be excised.

Syphilis of the Conjunctiva.—Chancre, papular syphilides, copper-colored spots, mucous patches, gummata, nodular syphilides, and syphilitic ulcer may affect the conjunctiva.

Chancre appears most frequently on the palpebral conjunctiva near the margin of the lid, where it presents an indurated circular red elevation of perhaps 1 centimeter in diameter, usually with a shallow ulcer at the top, having a gray base. Occurring in the transition fold or in the ocular conjunctiva, the base of the mass is distinctly indurated, and when grasped by the forceps is much like a piece of parchment lying in the mucous membrane.

Grouped *papular syphilides* are of rare occurrence; they accompany the same form of syphilide on the face and lids; the same may be said of the copper-colored spots, which are rarely seen.

Mucous patches are more common; they resemble the mucous patches as they appear on other mucous surfaces, are slightly raised, with a gray, even surface, and have a border of injected mucous membrane around them.

Gummata of the conjunctiva are extremely rare. Morrow states that they appear as small discrete tumors of the conjunctiva the size of a pea or bean.

Gummy tumor of the episcleral tissue and of the lids, affecting the conjunctiva, is met with. The growth is elevated and is soft. It may cause extensive destruction of tissue. It is differentiated from sarcoma by the effect produced on it by antisyphilitic treatment.

Nodular syphilides, manifestations of the later stages of syphilis, sometimes occur in the lids and produce *conjunctival ulcers*. Sloughs of large extent may result. In all of the conjunctival manifestations of syphilis the preauricular and cervical glands are more or less enlarged. Pain is not a prominent feature.

If recognized early, the *prognosis* in all cases of syphilitic affections of the conjunctiva is favorable. The condition responds readily to treatment.

Treatment.—If an ulcerated surface exists, it may be cleansed with a weak bichlorid solution (1 : 3000 or 1 : 5000), and calomel dusted on afterward. Vigorous antisyphilitic constitutional treatment should be given as early as possible.

Tumors and Cysts of the Conjunctiva.—**Congenital.**—**Dermoid Tumors.**—These usually develop near or at the sclero-corneal margin; they may be small, slightly elevated, and have a very few fine hairs projecting from them. They may cover a large part of the ocular conjunctiva, be markedly elevated, pigmented, covered with coarse hair, and contain numerous sebaceous glands. A dermoid growth sometimes develops in the conjunctiva and presents between globe and lid at the upper outer quadrant of the globe. It has much the appearance of a thickened nictitating membrane, is flat, has a rounded border, is pale, and often bears a few very fine hairs: movements of the eye downward and inward bring it readily into view. Dermoid tumors may be cystic; they may also contain much lipomatous tissue—*lipomatous dermoids*.

Vascular Tumors.—*Telangiectatic tumors* and *cavernomata* are observed. The former are often associated with similar growths on the lids. Both are benign, but tend to increase in size.

Benign Tumors.—Those that are not congenital are fibroma, lipoma, myxoma, osteoma, granuloma, papilloma, simple cystic tumors, and cysts due to cysticerci and echinococci.

Fibromata develop most frequently on the tarsal conjunctiva of the upper lid as a result of a chronic conjunctivitis; they are multiple, flat, and elevated one to two millimeters. *Lipoma* appears as a yellowish soft mass, usually in the retrotarsal folds. *Myxoma* appears in the form of polypoid masses developing from the margin of a wound or sinus, rarely from the conjunctival surface itself. *Osteoma* is a flat tumor developing in the ocular conjunctiva. *Granuloma* develops from wounds and from ulcerating surfaces. Papilloma is most frequently met with at the caruncle as a soft, villous mass. It may appear on any part of the ocular or palpebral conjunctiva, and is often mistaken for granulation-tissue. It is very prone to recur after removal, provided the removal is not complete. There is no tendency to the destruction of tissue. *Cystic tumors* are observed near the openings of the lachrymal ducts, in the retrotarsal fold, and at the caruncle. They are often due to chronic conjunctivitis. *Cysticercus cysts* are large, and usually present a white spot on the outer wall. *Echinococcus cysts* may be very large and extend far back into the orbit. Daughter cysts and hooklets may be found as part of the contents.

Treatment.—The most satisfactory treatment is excision. The vascular tumors should be removed as early as possible—the cavernomata especially—

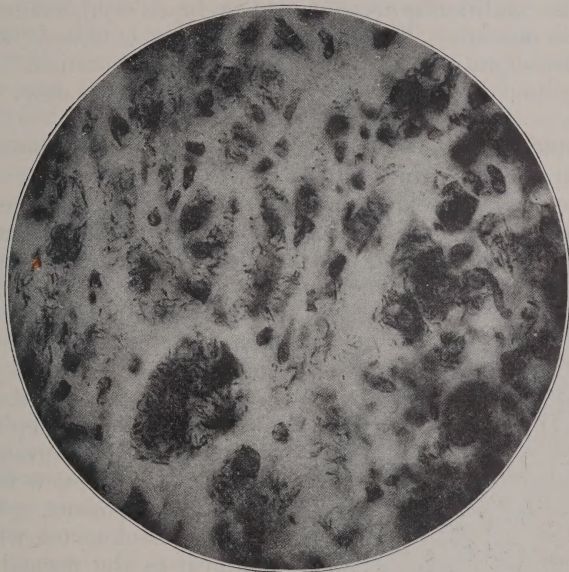


FIG. 200.—*Bacillus lepræ*, seen in a section through a subcutaneous node; $\times 500$ (Fraenkel and Pfeiffer).

as they may reach such enormous proportions if neglected that subsequent removal is impossible.

Malignant Tumors.—Epithelioma and sarcoma are the most common. A peculiar tumor, known as *cylindroma*, has been described by Hensel; it is probably a form of sarcoma.

Epithelioma of the conjunctiva accompanies epithelioma of the lid, although it may develop spontaneously from any part of the ocular conjunctiva. It appears as a small reddish elevation which soon presents an irregular, grayish, ulcerated patch with slightly raised borders and a congested base.

Sarcoma may develop in the shape of *pigmented* or *non-pigmented* polypoid masses springing from the retrotarsal fold and growing rapidly. It

may also develop at the limbus conjunctivæ. It appears in this location as a small red or pigmented spot; it may develop rapidly, but may also remain in a quiet state for a long period. Metastasis to the cervical glands or to remote parts of the body may occur.

Treatment.—Thorough removal of all diseased tissue by knife or cautery is the only way to make a favorable issue possible.

Leprosy of the conjunctiva occurs in connection with leprosy of the general system in nearly all cases; however, it may begin primarily in the conjunctiva. Morrow¹ cites one case in which a leprosy tubercle appeared on the eye and was mistaken for sarcoma. Cutaneous tubercles followed. Nodular masses may form in the conjunctiva which may persist for a long time, and may finally disappear, leaving non-vascular cicatricial tissue. The bacillus lepræ, to which the disease is due, is represented in Fig. 200. The writer has observed a mild persistent irritation of the conjunctiva accompanying leprosy, producing slight redness of the palpebral conjunctiva and increased lachrymation. Treatment is of little avail.

Lupus erythematosus is mentioned by Bowen² as attacking the conjunctiva. It appears as irregular plaques which are covered with small punctate excoriations or with grayish masses of exudation and superficial cicatrices. The condition is accompanied by lupus erythematosus of the face. The etiology is obscure. The disease progresses extremely slowly, and is accompanied by slight irritation and increased lachrymation. When accompanied by the same disease on the face the diagnosis is easy. Treatment is of little avail.

Tuberculosis of the Conjunctiva.—This affection presents two quite distinct clinical pictures, which will be considered separately:

First. When tuberculosis of the conjunctiva appears as an extension from adjacent mucous or cutaneous surfaces (*lupus vulgaris*) it presents slightly elevated, irregular patches having uneven, ulcerated surfaces, from which small granulations project; the patches may be small or large, and may appear on the palpebral (where they are most frequently met with) or on the ocular conjunctiva.



FIG. 201.—Tubercle bacillus in sputum (Fraenkel and Pfeiffer).

Pathology.—The tissue of the neoplasm shows loss of epithelium at the site of the ulcer, granulation-tissue, granular detritus, new-formed connective-tissue elements, giant-cells, and numerous leukocytes, which gradually diminish as the normal tissue is entered. A few tubercle bacilli are found in the tissue (see Fig. 201). The infection is most frequently by way of the lachrymal canals.

Symptoms.—There is slight irritation of the eye, accompanied by a scanty muco-purulent secretion which may persist for many months. Enlargement of the preau-

ricular gland on the affected side is present.

Diagnosis and Prognosis.—The coexistence of lupus on the nasal

¹ *System of Diseases of the Skin—Dermatology*, vol. iii. p. 587.

² *Twentieth Century Practice of Med.*, vol. v. p. 698.

mucous membrane or on the integument of face or lids, with a history of long duration, is usually sufficient. In a large percentage of the cases the mucous membrane at the inner canthus will be involved as a result of the continuation of the disease from the lachrymal passages. The condition may be confounded with epithelioma. If doubt exists, a piece of the tissue may be excised and examined microscopically, or the iris of a rabbit may be inoculated with the tissue. The prognosis is favorable in nearly all cases.

Treatment.—Excision of the diseased parts or destruction by means of the cautery is indicated.

Second. When tuberculosis of the conjunctiva is the result of direct inoculation the early stage is marked by a distinct congestion of the conjunctiva and the appearance of numerous small, discrete, grayish nodules in the ocular or palpebral conjunctiva which do not present an ulcerated surface. The *tubercle bacilli* are commonly introduced through wounds in the conjunctiva, made either accidentally or during operation involving the conjunctiva. The nodular masses present all the characteristics of miliary tubercles.

Symptoms.—Marked irritation of the eye, redness of the conjunctiva, increased lachrymation, and a muco-purulent secretion are present. The disease advances quite rapidly, producing hypertrophy of the conjunctiva and superficial ulcers. The preauricular and cervical glands on the affected side enlarge and break down. Ulceration of the cornea may develop.

Diagnosis and Prognosis.—Acute trachoma and syphilis are the only diseases with which this form of tuberculosis may be confounded. A section of a nodule, stained for tubercle bacilli and examined microscopically, will settle the question beyond doubt. The disease runs a very long and persistent course, and may involve other parts of the system. The eye may be completely destroyed.

Treatment.—It is doubtful if anything short of early removal of the affected conjunctiva will have any effect. After the active enlargement of the cervical glands has been established appropriate constitutional treatment, with attention to local symptoms as they arise, is all that can be done.

Pemphigus.—This disease of the conjunctiva is characterized by the appearance of very transient bullæ, followed by red, and later by grayish, areas on the conjunctiva of the lids and of the globe. As these areas heal the conjunctiva becomes atrophic, other patches appear, and further atrophy takes place; soon meridional bands between lids and globe are formed, and the condition known as *symblepharon posterius* is the result. The conjunctival surface becomes dry and shiny, the cornea opaque, and vision is lost. The condition is very rare: Horner observed it but 3 times in 70,000 eye cases.

Etiology.—Pemphigus usually accompanies *pemphigus vulgaris* or *pemphigus foliaceus*, and depends on a dyscrasia of the system. Individuals of all ages are attacked. A history of syphilis was obtained in only 1 of the 28 cases reported by Morris and Roberts.¹

Pathology.—The red raw surfaces evidently follow destruction of the upper layer of the epithelium due to a process which on the skin would produce blebs. The conjunctival epithelium, being thinner and much weaker, is cast off early. A deposit of fibrin soon forms over the affected area, and the grayish patch is the result. Sections of the atrophied conjunctiva show cicatricial connective tissue containing a few blood-vessels. The epithelium is thin and irregular.

Symptoms.—The progress of the affection is extremely slow; there is

¹ *Brit. Journ. of Dermatol.*, 1889, p. 175.

little secretion. With the advance in the atrophy of the conjunctiva dimness of vision increases. Both eyes are attacked.

Prognosis.—This is very unfavorable. The disease lasts for years, and usually results in loss of vision.

Treatment is of little avail. Arsenic may be given internally. Ointments and mucilaginous remedies may be employed to relieve the dryness of the conjunctiva. Surgical interference is seldom satisfactory.

Argyria Conjunctivæ (*Argyrosis*).—Long-continued use of nitrate of silver on the conjunctiva, particularly of a solution dropped into the eye, produces a discoloration which affects the ocular and palpebral conjunctiva, most marked in its lower half. The color varies from a light ochre hue to a deep brown. In some cases slight hypertrophy of the conjunctiva, with slight irritation, results. In one case observed by the writer the hypertrophied, non-inflamed conjunctiva formed a fold which projected into the palpebral fissure. At the request of the patient this fold was excised and the condition corrected. The stain formed is indelible. A solution of hyposulphit of sodium or of iodid of potassium in the strength of 1:10 of water has been suggested for the removal of these stains.

Affections of the Caruncle and Semilunar Membrane.—*Inflammation of the caruncle* is sometimes observed as a result of infection of one or more of its sebaceous glands. When this occurs the caruncle swells, becomes enlarged, and is much congested. The abscess opens spontaneously or may be opened with the knife; recovery will follow.

The hairs of the caruncle may become unusually large and numerous (*trichosis carunculæ*) and produce more or less irritation. Epilation, or excision of the hair-bulb will give relief.

Papilloma of the caruncle and semilunar fold occurs as a pink, soft, villous mass, with numerous papillæ, which are bathed in muco-pus. The mass bleeds easily and tends to increase in size. It is attended by a slight sensation as of a foreign body at the inner canthus, but gives little or no pain. Papilloma is prone to recur, and will do so unless thoroughly and completely removed. The knife or cautery should be employed.

Congenital telangiectasia of the caruncle has been observed.

The term *encanthis* is applied to an enlargement of the caruncle and semilunar fold from any cause. Enlargement of the caruncle accompanies all forms of conjunctivitis, and subsides with the subsidence of the conjunctivitis. Cystoid enlargement is at times seen. *Adenoma* may develop. Chalky deposits may form in the glands of the caruncle, which may cause it to become enlarged. *Carcinoma* and *sarcoma* (*encanthis maligna*) may develop primarily at the caruncle.

Treatment.—In the case of tumors at the caruncle and semilunar fold early operative procedure should be resorted to.

DISEASES OF THE CORNEA AND SCLERA.

BY SWAN M. BURNETT, M. D., PH. D.,

OF WASHINGTON, D. C.

Inflammation of the Cornea (*Keratitis*).—The cornea, having no vascularization of its own, depends for its nutritive supply on the blood-vessels of the conjunctiva, sclera, iris, and ciliary body. From this it happens—first, that inflammations of these tissues are nearly always accompanied by some change in the nutrition of the cornea; and, second, that defective general nutrition is apt to be felt early in the cornea as a tissue far from the base of supplies. Keratitis, therefore, when not the direct result of a traumatism, is in the vast majority of cases the expression of some depressed general vitality or is the effect or accompaniment of an inflammation in the adjacent parts. A *primary* and isolated keratitis is a rare affection, though the participation of other tissues may be so slight as to escape detection or be veiled by the intensity of the corneal affection.

Corneal inflammations may be studied clinically from the standpoint either of their supposed etiology or by following the anatomical divisions of the affected part. For practical purposes sometimes the one method and sometimes the other has been found the more convenient.

Anatomically, the cornea is a direct continuation of other coats of the eyeball—of the conjunctiva, through its epithelial layer; of the sclera, through the substantia propria; and of the uveal tract, through the endothelial layer of Descemet's membrane. The pathological importance of this connection will be apparent when we come to consider the various individual forms of keratitis.

Superficial Keratitis.—The most common form of this affection is that known as *phlyctenular conjunctivitis*, *phlyctenular kerato-conjunctivitis*, or *herpes corneæ*, but more properly as *strumous* or *scrofulous ophthalmia*, because it is usually limited to the conjunctival or epithelial layer of the cornea, and is always associated with the strumous diathesis or some form of defective assimilation.

Etiology.—The disease is confined almost entirely to childhood. One eye or both may be affected at the same time, and a recurrence of the affection from time to time is the rule. Evidences of a strumous diathesis are seldom lacking in its subjects. There is often swelling of the preauricular and submaxillary glands; the patients are badly nourished, even when not positively anemic, and the appetite is bad or capricious. In the worst cases the scrofulous cachexia is very pronounced. Running from the nostrils, which are clogged up with dried secretions, swollen *alæ nasi*, thick upper lip, and excoriated cheeks make the diagnosis before the eyes are inspected. Naso-pharyngeal disease, inflammatory or obstructive, which most frequently accompanies the affection, is the etiological factor in many instances. Phlyctenular disease often follows in the wake of measles and other exanthemata. It is more aggravated in warm and moist weather.

Micro-organisms have been described, but their etiological relationship to this disease has not been established (compare with page 286).

Objective Symptoms.—The disease manifests itself by a small yellowish-white elevation (the *phlyctenule*) on the surface of the cornea, varying in size from 1 to 2 or 3 mm. in diameter. It may occur at any place on the corneal surface, but its usual seat is near the scleral edge, and commonly on the limbus itself. It is not uncommon for two or more of these phlyctenules to appear at the same time, and on rare occasions they are so numerous as to form a circlet around the corneal base (*marginal phlyctenular keratitis*). The accompanying injection of the conjunctival vessels may be very slight, and is commonly limited to a leash of vessels running up to and ending in the *phlyctenule* (Fig. 202).

On the other hand, and especially when the spot is farther in on the corneal surface and the deeper structures are involved, the conjunctival congestion is more general. Oftentimes the accompanying conjunctivitis assumes

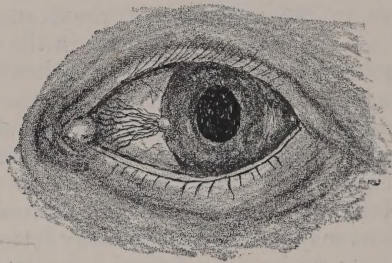


FIG. 202.—Scrofulous ophthalmia (phlyctenula corneæ).

the form of a more or less muco-purulent type. The intensity of the accompanying conjunctival participation, however, bears, as a rule, no proportion to the local lesion on the cornea.

Subjective Symptoms.—The subjective symptoms vary greatly in intensity. In the milder cases there is little or no pain, and a feeling of discomfort and an inability to use the eyes as much as customary are about all that is complained of.

In severe cases, which occur especially in children, the symptoms are of the most intense kind. There is a photophobia which makes the child keep the eyes tightly shut (*blepharospasm*), and which may persist for weeks, rendering even forcible separation of the lids difficult (see also page 253). The child seeks the darkest corner of the room, buries its head deep in the pillow, and violently resists every effort to bring it into the light. The *lachrymation* is profuse, and the cheeks are excoriated with the constant overflow of irritating tears.

Between this and the mildest form there is every gradation; moreover, the intensity of the symptoms does not bear any proportion to the extent of the pathological change. A single phlyctenule may be attended with more pronounced subjective symptoms than three or four, and the severity differs in different attacks in the same person. This can be accounted for partly, no doubt, by the fact that in the one case the exudate presses on the terminal filaments of the nerve distributed among the cells of the epithelial layer, causing these intense reflex phenomena, and in the other it does not. Another important factor, too, is the generally hyperesthetic condition of the patient, due, most likely, to defective nutrition of the nerve-centers.

Pathology.—Pathologically, the phlyctenule is not a vesicle with fluid contents, as its appearance would indicate. Under the epithelium there is found a collection of small round lymphoid cells, as shown in Fig. 203. The anterior epithelial wall of the phlyctenule breaks down; the cells are discharged, leaving a *small, superficial ulcer (phlyctenular ulcer)*, which is generally rapidly covered over by a fresh layer of epithelium, and the diseased process is ended for the time, usually leaving no trace unless the deeper

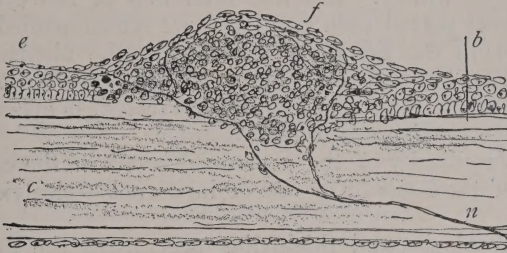


FIG. 203.—Phlyctenule: *b*, Bowman's layer; *c*, corneal substance; *d*, Descemet's membrane; *e*, epithelium; *f*, phlyctenule, consisting of a deposit of round-cells in the epithelial layer and along the course of the nerve; *n*, twig of nerve ending in epithelium (modified from Iwanoff).

structures of the cornea are involved, when there is likely to be more or less opacity remaining for a time or, it may be, permanently.

Diagnosis and Prognosis.—Direct inspection reveals the nature of the disease. The *prognosis* depends on the type. It is essentially a relapsing disease; repeated attacks may leave the corneal epithelium roughened and scarred, and sometimes covered with vessels, the so-called *phlyctenular pannus*.

Treatment.—In the treatment of the affection attention to the general condition is of greatest importance. A persistent and long-continued use of tonics and nutrients—among which iron (syrup of the iodid) and cod-liver oil are perhaps the best—is the first requisite as regards medication. But most important is the regulation of the diet and habits of the child. Only nutritious food should be allowed—milk, meat (except pork and veal) in moderate quantity, vegetables (except potatoes in excess), with abstinence from sweets and pastries. Good fruit may be allowed in proper quantities.

The child should live out of doors as much as possible in spite of the photophobia, and the function of the skin should be kept in proper order by frequent bathing. Any associated nasal affection should receive prompt and thorough attention, and the naso-lachrymal passages should be kept patulous.

Locally, in the first or acute stage, atropin drops (gr. iv– $\frac{3}{4}$ j) are to be used, and where there is much photophobia an equal amount of muriate of cocain can be added. A drop of this solution is to be put in the eye three times a day or every four hours according to the intensity of the symptoms. The eye should be bathed in water as hot as can be borne for five minutes every four hours.

In the second stage, after the rupture of the phlyctenule and the process of restoration has begun, the insufflation of finely-powdered calomel is a time-honored remedy, as is also Pagenstecher's salve (hydrarg. oxid. flav., gr. j, petrolat. $\frac{3}{4}$ j or ij) put under the eyelid and rubbed over the ball. In very mild cases, where there is no photophobia, lachrymation, or other sign of irritation, a simple antiseptic collyrium, such as boric acid or biborate of sodium, gr. x to $\frac{3}{4}$ j, will suffice, with care in the use of the eyes. The eyes should never be bandaged, protection from the excessive light being secured by colored glasses or a shade.

In the severest cases the blepharospasm is so intense as to require especial attention. When it has once become a fixed habit it is difficult to break up, and its presence undoubtedly prolongs the disease. It sometimes yields to the instillation of cocain, but in long-standing cases this will not suffice. In these instances the most efficient means is to plunge the face in a basin of cold water and hold it there a few moments. The shock of this violent procedure will usually relieve the spasm, and the child will, on removal from the water, open its eyes widely. Forceful dilatation of the eyelids by an eye-speculum for a short period each day has been recommended. The excoriations at the angles of the lids no doubt keep up the blepharospasm through reflex action, and should be cured as promptly as possible. After the disease has subsided any refractive error should be corrected, as eye-strain may excite an attack in an eye predisposed to this disorder.

Pannus.—Vascularity of the superficial layers of the cornea is often an accompaniment of trachoma or of one of its sequels—cicatricial entropion or trichiasis.

When the vascularity and thickening accompany the first stages of the disease, before the period of cicatrization has arrived, there are grounds for believing that the pannus is but an expression of the trachomatous process itself—*i. e.* a true trachoma of the conjunctival layer of the cornea—and not a secondary effect. In such cases the thickening is much greater than when

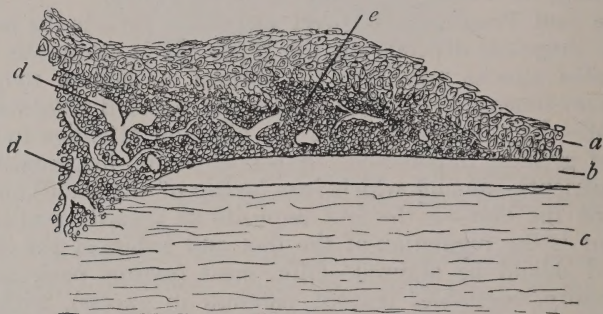


FIG. 204.—Pannus (after Iwanoff): c, the cornea; b, Bowman's membrane; a, thickened layer of epithelium; d, blood-vessels; e, infiltration of round-cells.

it is due to mechanical irritation by trichiasis or the rough cicatricial conjunctiva (see also page 291).

The denser forms of pannus have been called *pannus crassus*—the thinner, *pannus tenuis*. In *pannus tenuis* the blood-vessels are confined to the superficial layers, and there is not much infiltration or thickening of the epithelial layer; but in the denser form the infiltration may involve the deeper layers of the substantia propria (Fig. 204). The entire surface of the cornea may be covered, and the thickening so dense that the iris can no longer be distinguished. In the lighter forms only a part of the cornea may be involved, and in that case it is usually the upper portion.

It is seldom that a case of pannus runs its course without more or less loss of tissue, or *ulceration*. Occasionally, however, the pathological condition is one only of *hypernutrition*, characterized by the formation of new blood-vessels and connective tissue, and if there is no destruction of the substantia propria, the process may end with a complete absorption of the foreign material, leaving the cornea quite clear.

Treatment.—As the condition is usually secondary to some other patho-

logical process—trachoma, trichiasis, etc.—the treatment must be mainly directed against these affections. The existence of a pannus is no bar to the prompt and energetic treatment of these conditions; on the contrary, it improves *pari passu* with the amelioration of the original cause. Atropin, with cocain sometimes added (atrop. sulph. cocain. mur., $\bar{a}\bar{a}$. gr. iv- $\bar{z}$ j), and hot applications are the remedies proper to the relief of the symptoms of pain and photophobia, of which the corneal trouble is the immediate cause.

When the vascularization and opacity persist in any degree after the removal of the original cause, remedial measures addressed to the condition itself become necessary. These consist in diminishing, or in some manner cutting off, the blood-supply to the newly-formed tissue in the cornea or assisting in its absorption by the natural processes. The former may be accomplished directly by dissecting a narrow band of conjunctival tissue, 2 mm. wide, from around the base of the cornea (*peritomy*), or, as has been suggested, by cauterizing the tissues deeply with the actual or galvano-cautery.

The production of a violent inflammation of the conjunctiva by means of an infusion of or the powder of the *jequirity bean* had at one time quite a vogue in the treatment of pannus, but some unfortunate cases of total destruction of the cornea from its excessive action have caused it to fall into disuse except among a very few surgeons. The same may be said of inoculations with gonorrheal matter, which at one time were used, particularly in Belgium.

Curetting the surface of the cornea, especially in the earlier stages and before entropion or trichiasis has set in, can be practised with great benefit. For the less serious cases the ointment of the yellow amorphous oxid of mercury (gr. j- $\bar{z}$ ij), rubbed under the lids once or twice a day, assists in the process of absorption. For the same purpose insufflation of finely-powdered calomel is a remedy of old and established value.

Resorption or Transparent Ulcer of the Cornea.—A loss of tissue on the corneal surface, usually not very deep nor extensive, and not associated with any opacity of the corneal substance, is known as a “resorption ulcer.”

The distinguishing characteristics are its transparency and the smoothness of its surface, which is covered by normal epithelium.

The usual seat of the ulcer is near the center of the cornea. There is commonly but little lachrymation or photophobia, and there is scarcely any increased vascularization of the conjunctiva. An ulcer of this character is most common among the old and enfeebled, and is usually slow in healing. A slight traumatism is most probably the originating cause.

The ulcer usually heals without other interference than protection—with atropin and hot applications when the subjective symptoms are more pronounced than usual. In the chronic cases eserin has been found useful. The lesion may become converted into a true ulcer, with a tendency to spread through necrosis of the tissue.

When situated over the pupil a transparent ulcer gives rise to great disturbance of vision, quite as much so as an opacity of the same size, on account of the diffraction and diffusion of light through its irregular surface.

Herpes Corneæ (*Vesicular Keratitis*).—In those cases of *herpes frontalis* where the nasal twig of the fifth pair is affected and a vesicle is formed along the side of the nose, it is rare to have the cornea unaffected.

A vesicle containing a clear fluid forms on the surface of the cornea, ruptures early, and leaves a *superficial ulcer* or epithelial denudation, with infiltration and opacity of the surrounding parts. It is accompanied with

much pain of a neuralgic character, photophobia, and lachrymation. Occasionally, however, these violent symptoms are absent. The cornea itself is usually more or less anesthetic to touch, and the tension of the eyeball is diminished.

The vesicle differs from a phlyctenule of scrofulous conjunctivitis, with which it is sometimes confounded on account of the name *herpes conjunctivæ* by which the latter was formerly known, in that it is larger and its contents are fluid. Some opacity of the cornea nearly always remains (see also page 287).

Treatment.—The treatment is palliative—atropin alone or combined with cocain, hot applications, and an anodyne internally when the pain is exhausting. The general condition usually requires tonics and a sustaining nourishment. The author has found the salicylate of sodium in large doses useful in controlling pain and mitigating the severity of the disease. It has been suggested to scrape the ulcers and cauterize them, but unless they show a marked tendency to spread this course is not advisable.

Vesicles on the cornea have sometimes been found associated with *herpes labialis* or *nasalis*, especially in children, to which the name *herpes febrilis* has been given. The symptoms exhibit less intensity than those just described; there is little or no anesthesia of the cornea, and the globe-tension is not changed. These vesicles have been seen during malarial fevers. They all, however, seem to depend on some derangement of the central nervous system.

Dendritic Keratitis.—This name has been given to a species of superficial keratitis of a peculiar arborescent form (Fig. 205).

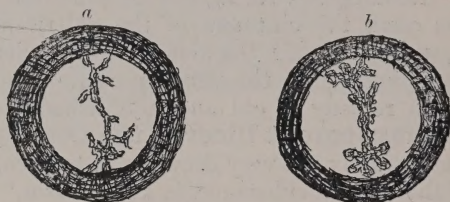


FIG. 205.—Dendritiform keratitis (after Galenga): a, first stage; b, seventeen days after.

It begins as a small vesicle, and continues its growth by a series of newly-formed contiguous vesicles which break down into small ulcers, forming irregular lines which give the distinctive name to the disease (Galenga, Horner).

Etiology.—Some authors regard the affection as mycotic, and no doubt micro-organisms are found in it, but none that are peculiar to it. It has been found associated with malaria (Kipp and others), and syphilis has been assigned as a cause by some writers. It seems most probable that the disease is the expression of a dyscrasia of some kind.

The ulceration occupies by preference the central portion of the cornea. The course of the disease is usually slow, and though, for the most part, not very annoying, is occasionally very painful and associated with severe supra-orbital neuralgia and tenderness, depending on the depth of the ulceration and the amount of involvement of the terminal filaments of the nerves.

Treatment.—This consists in rest, protective spectacles, atropin, and hot applications. Should there be a marked tendency to spread or an obstinacy in healing under the above treatment, the ulcer should be scraped and 1 : 60 formalin solution applied, or in severe cases the actual cautery. Quinin and arsenic internally are useful. Galvanism along the supraorbital nerve has been suggested.

Filamentous Keratitis.—On rare occasions, after rupture of corneal vesicles, a rope-like body is seen attached to the surface of the ulcer, its free end being frayed (Fig. 206). This is the *filamentous keratitis* of Leber and Nuel. It consists of epithelial cells and coagulated fibrin twisted into the form of a cord.

Superficial Punctate Keratitis.—Under the head of superficial keratitis must also be admitted a form of corneal inflammation called by Fuchs *keratitis punctata superficialis* (Syns.: *Keratitis subepithelialis centralis*; *Keratitis maculosa*; *Noduli corneæ*; *Relapsing herpes corneæ*).

The alterations in the cornea consist of small gray dots arranged in groups or short rows in the superficial layers, mostly near the center. The disease begins with a rather pronounced catarrhal conjunctivitis, and is usually associated with catarrhal disease of the respiratory tract. The dots remain sometimes for weeks. Stellwag has described a similar affection, the foci of larger size being found in the periphery of the cornea. There is much pain, and iritis may develop (*nummular keratitis*).

Treatment.—Hot applications, atropin, and protection of the eye with dark glasses.

Fascicular Keratitis (*Keratitis in Bandelette*).—This affection, which bears a resemblance to the phlyctenular form of keratitis, and of which it may be a modified form, is characterized by a band or leash of vessels, with a narrow border of opaque corneal tissue, which traverses the surface of the cornea to end near the center in a small round whitish-yellow head (Fig. 207).

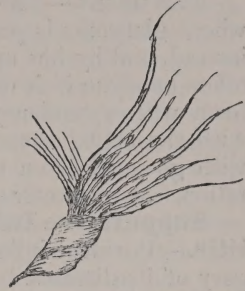


FIG. 206.—Filamentous keratitis (after Panas).

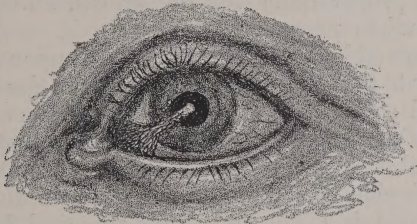


FIG. 207.—Fascicular keratitis.

On disappearance of the vessels a more or less opaque band or streak is usually left on the cornea. More than one of these bands may appear at the same time or develop consecutively. The *treatment* is the same as that suited to keratitis in general.

Bullous Keratitis.—In eyes whose nutrition has been seriously interfered with, as it is likely to be in glaucoma, irido-cyclitis, or choroiditis, an extensive elevation of the epithelium is sometimes observed at or near the center of the cornea. The bleb, thus formed, is usually partially filled with a clear fluid which gravitates to the bottom, giving it a baggy appearance. The same phenomenon has also been observed a few times in eyes that are not thus disorganized. There is slight pericorneal injection, but the pain is usually quite severe and of a more or less intermittent character. The anterior layers of the cornea are seldom exempt from implication.

The disease seems to be purely local in character, not depending upon the general condition, as does, for instance, *vesicular keratitis*.

A *recurrent form* following injuries has been noted by Hansen Grut.

Fuchs and some others seem to think that the elevation of the epithelium is due to an obstruction in the lymph-circulation.

Treatment.—The disease is to be treated by instillations of atropin, except where glaucoma is present or feared, when eserin ($\frac{1}{2}$ to $\frac{1}{4}$ gr.— $\frac{1}{2}$ j) can be used instead, and by hot applications for the mitigation of pain, with an opiate or other anodyne if it does not yield to these mild measures. Should an ulcer form with a tendency to spread, it can be touched with formalin, 1:60, or with the actual cautery. In the milder forms insufflations of iodoform act with good effect on the ulcer and the pain. Cocain can be used in moderation. A protective bandage is usually beneficial.

Suppurative Inflammations of the Cornea or Suppurative Keratitis.—Purulent inflammations of the cornea form the most important category of its diseases, because of their immediate and remote dangers.

Suppuration of the corneal tissue is always followed by ulceration or destruction of the substance, leaving invariably an opaque cicatrix as a sequel, thus annulling one of its most necessary qualities—its transparency.

These inflammations may not only eventuate in a total destruction of the cornea itself, but on occasion lead to an involvement of the whole eyeball, ending in its disorganization. They demand our most earnest attention, moreover, from the fact that they are truly infectious in their nature, and are, thus far, to be classed among the preventable diseases.

Etiology and Pathology.—We know, since the great work of Leber,¹ that for the genuine infecting process we must have a micro-organism, and that usually it is introduced from without. For this reason these infectious affections of the cornea are common among those working out of doors and in the dust, as laborers, harvesters, etc. But not only must we have the organism, but also the soil made ready for the seed, and the tissue must be in a condition to serve as a proper nidus for the growth and development of the particular micro-organism present.

Few organisms are able to obtain a foothold upon a perfectly healthy tissue, with the power to throw out white blood-corpuscles to act as phagocytes. The wounded normal corneal tissue always heals without suppuration when free from any infecting organism. The epithelium of the cornea, when intact, interposes an almost insuperable barrier to the entrance of germs, and when we find an infection we may be almost certain that a destruction of epithelium has preceded it. The important practical lesson to be learned from this is, that with proper precaution and early attention many, if not most, of these destructive suppurations can be avoided.

All injuries and wounds to the cornea should be promptly treated by disinfection, or at least by thorough and frequent cleansing with an aseptic liquid, as boric acid or mild bichlorid or weak formalin solutions. Bandaging the eye closely under these conditions is of doubtful wisdom. The heat of the bandage hastens the development of what germs may yet remain in the conjunctival sac or on the lid-margins. An absolute disinfection of these parts has not yet been found possible by any safe procedure.

For clinical purposes suppurative diseases of the cornea can be considered under several heads, based on their etiology, course, particular complications, and special features; but the general characteristics are the same in all, and all begin in essentially the same manner.

There is first noted at the place of infection an infiltration of a pearly-gray color which rapidly turns to a creamy yellow. This infiltration spreads to a greater or less extent, remaining circumscribed only in a genuine “ab-

¹ *Die Entstehung der Entzündung*, Leipzig, 1891.

scess." In the eroding or serpiginous forms this extension is sometimes very rapid. On the other hand, it may be slow, but steady in its progress. The part of the cornea affected loses its vitality, sloughs off, and an *ulcer* is formed. This destructive action of the micro-organism is arrested, it is claimed, by the phagocytic power of the white blood-corpuscles. A limit is thus set to the invasion of sound tissue, and the healing begins by the re-formation of epithelium at the edge of the ulcer. The process of reparation goes on, when the loss of tissue is not extensive, to a complete restoration of the original form, but usually with a substance not of the nature of the true corneal tissue. It is cicatricial in character, and not transparent, except perhaps in those cases where the destruction is very limited in extent. The membrane of Bowman is never re-formed when it is once destroyed, but the epithelium is very readily re-established. While the pathological processes in all cases of suppuration are essentially those just recited, for the purposes of clinical study and treatment they have been classified under several distinct varieties.

Abscess of the Cornea.—This is a simple circumscribed collection of pus in the corneal substance, usually some distance from the scleral edges.

It is most commonly seen as a sequel or continuation of a phlyctenule on the surface, the throwing off of the epithelium opening up the way to an infection of the deeper parts. The subjective *symptoms* are the same as in other forms of keratitis. It terminates by a breaking down of its anterior wall and a discharge of its contents, becoming thereby an *open ulcer*, which under favorable circumstances heals in a few days, and, if the loss of tissue is not great, leaving little opacity. It may be induced by any other means that destroy the epithelial layer, such as small wounds, foreign bodies, etc. The so-called *ring abscess*, where the suppuration extends around the base of the cornea, is seen mostly after cataract operations.

Treatment.—The proper treatment is hot applications, atropin solution (gr. iv- $\frac{3}{4}$), a drop three times a day, with rest and protection of the eyes. A spontaneous rupture is usually allowed. When the ulcer is formed its healing is expedited by aseptic applications of weak formalin solution, 1 : 2000, or boric-acid solution, or other means to be mentioned in succeeding paragraphs.

Ulceration of the cornea, or destruction of the corneal substance, is the essential feature of all forms of *suppurative keratitis*.

Varieties.—The forms of corneal ulceration, from a clinical standpoint, depend upon its seat, its cause, its course, and its association with other pathological conditions. Thus we have the *sthenic* and *asthenic* ulceration, according as the accompanying vascularization and other symptoms of irritation are considerable or mild; *marginal* ulceration, when it is seated near the margin of the cornea; *serpiginous* ulceration, when it creeps over the surface of the cornea, invading successively the adjoining areas; *keratitis with hypopyon*, when associated with the presence of pus in the anterior chamber; and other distinctive titles. Moreover, all these varieties, or any number of them, may be only different or successive phases of the same attack. In all, the essential clinical features are the same, modified, however, by the particular circumstances of individual cases.

Under this head may be mentioned a rare form of chronic *creeping ulcer*, which begins near the margin of the cornea and progresses in a crescentic form without any pronounced suppuration or hypopyon, never leading to perforation, but followed by dense cicatricial opacities. To this the name *rodent ulcer* has been given.

A form of spreading keratitis is observed very often in those engaged in shucking oysters—the so-called *oyster-shucker's keratitis*. It was thought to

be a purely infectious disease until Randolph of Baltimore demonstrated that it was not, but a mechanical keratitis caused by the fine particles of lime of the oyster-shell. The *harvester's keratitis* is probably first mechanical and afterward microbic.

Etiology.—The immediate causes of destructive ulcers of the cornea are usually infecting wounds or injuries of some kind, including operations, such as cataract extraction, iridectomy, and other operations involving the cornea. Anything that destroys the epithelium opens up the way to the entrance of infecting micro-organisms. These germs may be introduced at the time of injury or they may enter later. Two factors are necessary for development of the process—the germ and the soil. As there are always germs in the conjunctival sac, or as they can easily get entrance there, some of which may be pyogenic, any injury of the cornea is liable to take on an ulcerative action if the tissue is in a condition of non-resistance, as, for instance, in the case of weak, poorly-nourished people. The progress of the ulceration may be very brief, the reparative process setting in in a few days, or it may continue for weeks without showing any tendency to heal, or may extend itself slowly, but persistently, into the sound tissue.

The germs most commonly found as the active agents primary in corneal ulcerations are the usual pyogenic forms—principally *staphylococcus* and *streptococcus* (see Figs. 192 and 197)—but Uthoff, Axenfeld, and others have recently (1896) found the *pneumococcus* in great abundance in serpent ulcers (Plate 2, Fig. IV.), and Leber has found a form of *aspergillus* in some cases. Probably the most frequent cause of large destruction of the cornea is the *gonococcus* of Neisser found in purulent ophthalmia of gonorrheal origin (see article on the Conjunctiva).

Symptoms and Course.—An ulcer begins with a focus of infection, noticeable as a superficial defect with ragged edges of a yellow color and surrounded by a zone of infiltrated cornea. Its sides and bottom are covered by a detritus of dead corneal tissue, having a yellow pultaceous appearance. The accompanying vascularization of the conjunctiva varies greatly. In some instances it is pronounced, the swelling of the tissue around the base of the cornea in the vicinity of the ulcer being very marked.

There are at times great photophobia and much lachrymation and pain, which, however, in the indolent forms may be lacking almost entirely.

In the *serpiginous form* the ulceration spreads gradually over the surface, and usually with increasing depth. Then some time during its course there is an appearance of pus in the bottom of the anterior chamber—*hypopyon* (Fig. 208). This may occur while the ulcer is still central and there is yet clear cornea between it and the scleral margin. It was held at one time that it was necessary to have a perforation of the posterior wall of the ulcer through the membrane of Descemet in order that pus might find its way into the anterior chamber. The researches of Leber have shown, however, that the pus-cells may gravitate down through the sound corneal tissue and pass into the anterior chamber at the iris angle, or they may originate at this point from a participation of the uveal tract in the inflammatory process. In certain cases no doubt there is a small perforation of Descemet's membrane.

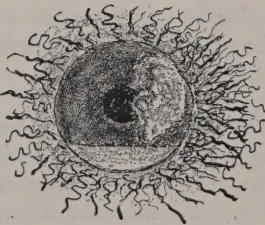


FIG. 208.—Large serpiginous ulcer with hypopyon.

The destruction of tissue may be very extensive, covering the entire anterior surface, leaving the posterior layers and

the membrane of Descemet intact; in which case there will be no *perforation*. In most cases, however, this is the event, and we have as a consequence a new set of phenomena and complications.

With the opening of the anterior chamber the aqueous humor escapes; the iris falls forward against the posterior wall of the cornea, plugs up the opening, and in course of time may become united to it by adhesive inflammation (*anterior synechia*). The anterior chamber then refills, leaving this portion of the iris in front of the mass of aqueous humor. If the opening is large enough, the pressure from behind is sufficient to push the iris through the opening and form a bag of greater or less size in the site of the ulcer. We then have *perforation with prolapse of the iris*.

It may happen that the pyogenic germs entering the anterior chamber find a suitable nidus for their development in the iris, ciliary body, and choroid, and, setting up a purulent inflammation in these tissues, leaving about the condition of *panophthalmitis*, leading to final *atrophy of the eyeball*. There is no case of hypopyon probably in which the iris is not more or less affected.

Prognosis.—From what has been said it may be inferred that the prognosis depends upon the activity of the morbid agent and the ability of the tissues to resist its encroachment. In the old and feeble it is much more serious than in the young and strong.

Treatment.—Suppurative keratitis being an infectious disease, the treatment should be both preventive and therapeutic. Every injury of the cornea should be considered as if it were infected. The conjunctival sac should be thoroughly cleansed with an aseptic liquid, as a saturated boric-acid solution or formalin 1 : 2000, and kept as aseptic as possible. The seat of injury itself should be touched with a 1 : 60 formalin solution, or nitrate of silver (gr. xx- $\bar{3}$ j), or tincture of iodine, when there is strong suspicion of infection, and, where it is reasonably certain, with the actual cautery. The treatment of the ulcer when it has declared itself should be antiseptic and palliative. The surface of the ulcer should be touched with a 1 : 60 formalin solution once a day so long as there seems to be any tendency to spread. Formerly the author was accustomed to use full-strength carbolic acid for this purpose with good effect. Mules recommends iodoform applied on a wafer of gelatin directly to the ulcer, bandaging the eye to keep it in place. The iodoform may be dusted directly on the ulcer, but this is less efficacious. When the serpiginous character becomes pronounced, the actual cautery applied to the edges and bottom of the ulcer becomes necessary. This must be done under cocaine. It is well to scrape away as much dead tissue as possible with a sharp spoon before applying either the cautery or the formalin caustic solution. Tincture of iodine and nitrate of silver (gr. xx-f $\bar{3}$ j) are also applied to the curetted area. The cauterization may be repeated every two or three days, according to the urgency of the symptoms. Curetting of the ulcer while a fine spray of a 2 per cent. solution of boric acid is directed against its surface has been recommended. Sämisch recommended an incision into the anterior chamber through the sides and bottom of the ulcer in the serpiginous form, and this operation is still performed by many surgeons. Its performance before a hypopyon is formed is in the majority of cases not advisable, since it makes easy the entrance of germs into the interior of the eye. In cases of hypopyon this objection does not hold to the same extent. It is often necessary to let out the pus when present in large quantity, and in these cases the incision should be made as low down as possible (see also p. 567).

Quite recently the *subconjunctival injections* of bichlorid of mercury have had many advocates. A few drops of 1 : 2000 solution are injected under

the conjunctiva once a day or every other day. The operation is generally very painful, even under cocain. Others have found the injection of a normal salt solution quite as effective. As palliatives atropin and cocain are the main reliance. The latter should be used only for the temporary relief of pain and the lowering of intraocular tension. Eserin in weak solution ($\frac{1}{4}$ to $\frac{1}{2}$ gr. ad $\bar{3}$ j) is used for the same purpose if iritis is not a complication.

As a palliative and curative agent heat is most valuable. As the morbid process is to be stopped, or at least retarded, by the phagocytic action of the white blood-corpuscles, a determination of fresh blood to the part, with dilatation of the vessels, is all important. Heat accomplishes this, and the best form of application is fomentation with water as hot as it can be borne for five minutes every three or four hours. The immersion of the eye in a goblet or glass of hot water, as recommended by Leartus Conner of Detroit, is an elegant and most efficient way of administering heat.

The eye should not be bandaged, except when the ulcer is very deep and there is danger of spontaneous rupture, under which circumstances the *dry antiseptic pressure bandage* is effective.

In cases of perforation the management is little different, except as to the treatment of the *prolapse of the iris*. When the prolapse is not large and is situated peripherally, and does not involve the sphincter, eserin should be substituted for atropin. Its myotic action tends to draw the iris out of the wound, and often quite successfully. If the condition of the conjunctiva warrants it, a pressure bandage aids in reducing a hernia of the iris. The prolapsed iris should not be excised or punctured, certainly not until the suppurative process has ended, and then only under strictest asepsis. Even very large prolapses smoothe down in time.

Careful attention must be paid to the general condition of the patient, particularly in the old and feeble. Tonics, and even stimulants, with the most nutritious diet, are indicated.

There are two forms of secondary purulent keratitis which require a brief separate mention :

(1) **Ulcerations following Purulent Conjunctivitis.**—Under these circumstances the two most potent factors are united in the development of the disease in its most destructive form—namely, the presence of an infecting germ and a denuded and macerated condition of the epithelium, with diminished nutrition of the cornea from the pressure of the chemosis on the surrounding nutritive vessels. The ulceration usually begins at the periphery of the cornea under a fold of overlapping chemosis. Quite often, however, it commences near the center, and occasionally there is a necrosis of the whole cornea at once from the cutting off of its nutritive supply by pressure—a true *sphacelus corneæ*—when the entire tissue becomes yellow and breaks down into a pul-taceous mass. The presence of the corneal ulcer, however great its extent, is not a bar to the most energetic treatment of the conjunctival disease (see also page 279). The ulceration is apt to be deeper than in other forms, especially at the periphery, and there is an earlier prolapse of the iris. Often the whole iris seems to bulge forward either as a mass—*keratocele*—or through numerous perforations in the apparently clear cornea—the so-called mulberry appearance—and the eye seems doomed to destruction. There is, however, in many of these cases quite a quantity of sound corneal tissue remaining. The membrane of Descemet resists destruction for a long while, and eyes that seemed lost regain their form and some part of their function.

In cases of peripheral perforation eserin is to be used, while in other

forms atropin and antiseptis, with hot applications, should constitute the main local treatment.

(2) **Neuro-paralytic Keratitis.**—The other form of secondary keratitis is that associated with paralysis of the fifth pair of cranial nerves, the so-called *neuro-paralytic keratitis*. When the fifth nerve, particularly the part containing fibers of the sympathetic, is divided in animals, in a short time the cornea on that side begins to ulcerate, and soon passes on to total destruction. The same thing is likely to occur in man when the fifth nerve is from any cause paralyzed, and particularly when the branch of the seventh going to the orbicularis is at the same time involved.

It has been a point in dispute whether the ulceration is due to interference with nutrition from injury to the trophic filaments in the fifth pair, or is simply the result of the traumatic injuries inflicted on the insensitive cornea on account of its constant exposure from the paralysis of the orbicularis. It would seem from a careful sifting of the evidence that both factors play a part. Injury to the trophic nerves seriously impairs the resisting power of the corneal tissue, and, it may be in some instances, is of itself sufficient to bring about destructive inflammation, independent of serious injury, for we see the ulceration sometimes when the orbicularis is intact. On the other hand, we have paralysis of the orbicularis without corneal ulceration.

The process usually begins as a marginal ulcer, with deep injection of the conjunctiva, and spreads gradually over the whole cornea, the tissue breaking down into a soft yellow mass. On occasion the process seems to arrest itself, and a small amount of clear cornea is left. It is usually painless, and not accompanied by photophobia or lachrymation.

The course is slow and **prognosis** serious, a total destruction of the cornea being the result to be expected.

Treatment is wholly palliative, protection of the eyes by bandage or stitching the lids and cleanliness being the main features in the therapeutics. Tonics and a nutritious diet are nearly always demanded.

After removal of the Gasserian ganglion Dr. W. W. Keen and Dr. de Schweinitz recommend primarily stitching of the lids, and when the first dressing is made the application of a Buller's shield, which remains for a week or more. With these precautions they have prevented corneal ulcer after complete excision of the ganglion. Destructive ulceration of the cornea is the result most to be feared in *diphtheria* of the conjunctiva (page 284).

Keratitis e Lagophthalgo.—When the cornea is continuously exposed from any cause its epithelium desiccates and falls off, and there is a liability to the entrance of germs with an infective keratitis as a result.

The affection has been observed in excessive exophthalmos, destruction of, or cicatricial contraction of the eyelids, paralysis of the orbicularis, etc.

The keratitis pursues practically the same course as neuro-paralytic ophthalmia, though not usually with the same rapidity or malignancy, and responds more promptly to treatment.

Treatment.—This consists in removing the cause when possible, and usually by some operation on the lids. In case this cannot be done a protective bandage must be constantly used. In the slighter forms of lagophthalmos the bandage should always be applied at night, and all such eyes should be protected against dust, wind, smoke, and other irritating influences. The treatment of the keratitis itself is the same as that indicated for keratitis in general.

Corneal Ulcers in Small-pox.—In the days prior to vaccination

destruction of the cornea from small-pox was one of the most common forms of blindness. Happily, it is not often encountered now.

True *vaccinal abscess* differs from ordinary abscess in that it is generally endogenous, being simply the appearance of a variolous pustule on the cornea itself. That it may be due to secondary infection is, however, possible, especially if the cornea becomes involved after the stage of eruption is passed.

The treatment is the same as that for other forms of purulent keratitis.

Keratomalacia.—This is a form of destructive corneal trouble met with mostly in badly-nourished infants and children, though adults with vital powers greatly reduced by lack of proper food are also liable to be attacked. It is seen accompanying meningitis, variola, measles, and severe diarrhea or dysentery.

Symptoms.—It is always associated with *xerosis of the conjunctiva* (page 296). There is great dryness of the conjunctiva, which is covered in spots with a froth-like material that is found upon examination to consist of fatty matter and epithelial cells. The lachrymal secretion is deficient or entirely lacking. The cornea becomes dry and cloudy from a drying of its epithelium, and soon shows evidences of breaking down at the center. This disintegration is of the color of pus, and sometimes extends very rapidly, destroying the cornea in the course of a few hours. Sometimes, however, it requires several days to accomplish this. It may even happen in mild cases that the whole tissue is not destroyed. There is, in those who are old enough to express themselves, a pronounced *night-blindness* at the beginning of the affection. This, as well as the other characteristic symptoms, gives evidence of a lack of nutrition at the nerve-centers.

Microbes of various kinds have been found in the secretions, but they are probably not the essential cause of the disease, but only find in it a nidus for growth. The one most frequently found is a small bacillus, the so-called *pseudo-diphtheria bacillus*, and is often present in large numbers.

The prognosis is most unfavorable; the patients frequently succumb to the disease which has caused the keratitis or to an intercurrent pneumonia.

Treatment.—The first object in treatment is to improve the nutrition as rapidly as possible by the most nourishing foods, tonics, etc. The eye itself should be treated with hot fomentations, mild aseptic washes. Caustics are seldom called for. On account of the insensitiveness of the eyes and the tendency of the lids to remain open, a bandage is necessary for protection.

Tuberculosis of the Cornea.—*Primary tuberculosis* of the cornea is a rare affection. The cornea, however, usually participates more or less in the conjunctival form of that affection (page 302).

Symptoms.—In the few cases that have been reported it has begun as an interstitial opacification, commencing at the edge and progressing toward the center of the cornea. In this affected area there are to be seen small yellowish-white granules like miliary tubercles, which coalesce and finally break down, and are thrown off, leaving an ulcer usually without hypopyon. A bacteriological examination or experimental inoculation will usually demonstrate the character of the disease.

The treatment is the same as that for other ulcers, only demanding an early scraping or destruction by caustics of the affected tissues.

Interstitial or Parenchymatous Keratitis (*Syphilitic, Inherited, Specific, Diffuse Interstitial Keratitis*).—In contradistinction to the destructive forms of corneal inflammation we have been considering, this form does not lead, as a rule, to a loss of corneal tissue. Moreover, it is always the man-

ifestation of a systemic derangement, and usually some form of dyscrasia, hereditary syphilis being the most common. Its association with acquired syphilis is uncommon, nor does scrofula usually manifest itself by this form of corneal inflammation.

Etiology.—We owe to Hutchinson the discovery of the intimate connection of keratitis parenchymatosa with inherited syphilis. The ground taken by him nearly forty years ago is still maintained by a large part of the ablest clinicians.

Still, it may be questioned whether all cases of interstitial keratitis are syphilitic. Von Hippel has found the disease very frequent in people of a tuberculous taint with no history of inherited syphilis. Of 87 cases, 23 were syphilitic and 15 doubtful; 18 tuberculous and 8 doubtful—other cases uncertain. Parinaud found 96 per cent. of his cases syphilitic; Despagne, 14 per cent.; Sklasy, 30 per cent.; Bosse, 44 cases in 54.

The syphilitic cases are generally marked by definite and peculiar features. As regards the mother, there are rarely absent histories of abortions or early death of other children, and those now living show more or less evidence of being affected. Probably the most characteristic appearance is on the part of the permanent teeth. The central upper incisors have notched edges and are peg-shaped, the so-called "Hutchinson's teeth." This shape is due to defective nutrition and the breaking away of the enamel. There are often nodosities on the tibia, and the frontal tuberosities are unusually prominent. There are often deep scars around the angles of the mouth and the *alæ nasi*. It is usual to describe the skin as being coarse, but the author's observation is that it is commonly unusually fine and velvety in texture. This is particularly noticeable in the negro race. A less common accompaniment is that of deafness. Synovitis of the knee-joint may be a complication, and there are likely to be other evidences of faulty nutrition. The disease is commonest between the ages of five and fifteen, occurring occasionally as early as the third year and rarely as late as the sixtieth year. A *congenital form* has been described. In female children it is apt to appear about the supervention of menstruation.

Cases occurring in persons above thirty years of age are not, as a rule, due to syphilis, but to some other dyscrasia, as rheumatism, gout, and possibly tuberculosis, or the climacteric.

Symptoms.—The disease begins as a grayish opacity in the substance of the cornea, sometimes at more than one place, and gradually extends in typical cases until the whole of the tissue is involved. This opacity is so dense in fully-developed cases as to entirely veil the iris from view, and is generally quite uniform, though a close inspection will reveal foci of more intense infiltration.

At the beginning the epithelium is intact and the surface of the cornea has its normal glistening look, but later it becomes rough like ground glass, showing a disturbance in the arrangement of its epithelial cells.

In a form to which the name *circumscribed* or *discrete* has been given there may be several spots at some distance from each other and apparently unconnected. An examination with oblique illumination and a magnifier, however, will nearly always show some fine streaks of opacity connecting them.

In this discrete form, which is more frequently found in the rheumatic diathesis and in women about the climacteric, there is nearly always a per-



FIG. 209.—Form of the upper teeth in keratitis parenchymatosa (after Hutchinson).

manent opacity remaining after the disease has subsided, more especially when the spots are near the scleral border (Fig. 211).

During the very early stage of the infiltration there is no great increase



FIG. 210.—Interstitial keratitis, with commencing vascularization.

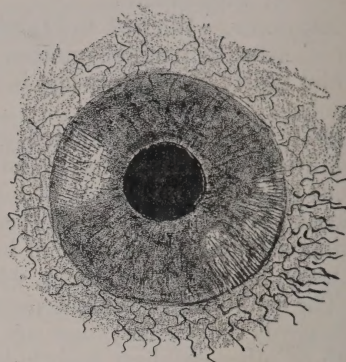


FIG. 211.—Circumscribed interstitial keratitis (author's case).

in the vascularization of the conjunctiva, nor are photophobia and lachrymation very pronounced.

The *second stage*, that of vascularization, is almost always attended with symptoms of irritation. This vascularization of the infiltration is the natural process for its absorption. Its manner of invasion is characteristic and distinctive. The vessels, which are very fine and delicate, are seen to penetrate deeply into the substance of the cornea at its periphery. On account

of their fineness and compactness they seem, as seen through the hazy corneal tissue, almost like an extravasation of blood into its substance—the “salmon patch” of Hutchinson.

The vascularization usually advances *pari passu* with the progress of the infiltration across the cornea, and that is usually from above downward, so that by the time the infiltration reaches the opposite side the cornea looks like a piece of raw beef—the *vascular keratitis* of some writers. This may have required weeks or even months, for tediousness is a prime characteristic of the affection (Fig. 210).

The accompanying symptoms may be mild, giving rise to but little pain. In most cases, however, there are considerable pain of a neuralgic character and lachrymation, and there are generally indications of the

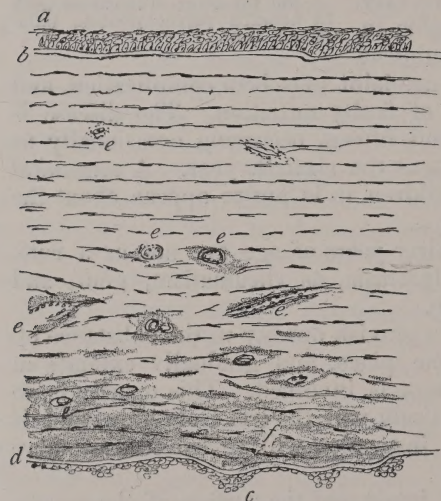


FIG. 212.—Section of the cornea in parenchymatous keratitis: *a*, epithelial layer; *b*, Bowman's membrane; *d*, membrane of Descemet with deposit of round-cells, *c*, on its posterior surface; *e*, blood-vessels; *f*, infiltration and dislocation of the corneal layers (modified from Nordensen).

involvement of the uveal tract. In fact, few cases run their course without an implication of the iris, ciliary body, or choroid, or all three. Stellwag designated the disease as “*anterior uveitis*.” We must remember that the cornea is connected directly with the uveal tract through the endothelial

layer of Descemet's membrane. Unfortunately, the condition of the cornea does not allow us to examine carefully into the state of the iris, but after the opacity has cleared up we are apt to find evidence of iritis. Retinitis and optic neuritis may occur, and secondary glaucoma is not uncommon.

All cases, however, do not run such a typical course. A part of the cornea may be attacked, vascularize, and clear up, and then another and another, until the whole tissue has been successively affected. The process may occasionally stop after an attack on a limited portion. A number of cases of an *atypical form*, which are not properly forms of interstitial keratitis, have been reported in which the opacities are stripe-like or ring-like. These present the appearance of pus in the corneal layers, the so-called *abscess-forms*, or they may appear as a *central annular* lesion. On rare occasions *ulceration* and *hypopyon* are accompanying conditions, but should be regarded as incidental complications.

Prognosis.—The course of the disease is invariably slow, and, as the eyes are liable to be affected in succession and the same eye experience more than one attack, many months or even years may not see the end. And yet the prognosis *quoad visum* is generally good, and particularly is this so when the uveal tract is not seriously involved. In many cases the cornea clears up almost perfectly, though an examination with oblique illumination and corneal loup will reveal some faint streaks of opacity; indeed, years after an attack of interstitial keratitis minute vessel-channels, nearly straight, branching at acute angles and short bends, may be detected in the cornea. These are best studied with the ophthalmoscope, after dilating the pupil, through a strong convex glass (+16 D.) (Fig. 213). The process of resolution always begins at the periphery of the cornea.

Treatment.—The disease is essentially self-limited, and we can do but little to shorten its course. Yet we are not without resource for the allevia-

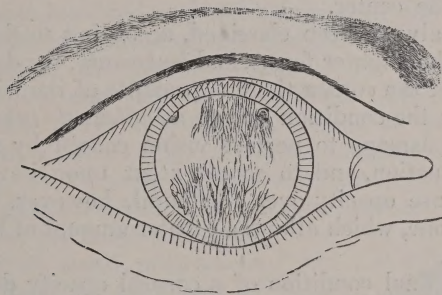


FIG. 213.—Vessel-formation in the cornea after interstitial keratitis (Hirschberg).

tion of its uncomfortable symptoms and measures to encourage a favorable issue of the disease. As resolution takes place through vascularization, means which increase this are in order, and chief among them are hot applications. The eye should be bathed in water as hot as can be borne for five minutes every four hours. This also assists in relieving any pain that may be present. Atropin, 1 per cent. solution, dropped in the eye three times a day is beneficial, not only for the corneal affection, but also for the iritis which may be present. When the long-continued use of atropin sets up a papillary inflammation of the conjunctiva—which it may do on very rare occasions—hyoscya-min, scopolamin, or daturin may be substituted for it. Being a diathetic disease, general treatment is all-important, especially iron, arsenic, and cod-liver oil. Tonics and good nourishment are called for in cases of debility, while

rheumatism and gout and tuberculosis require their appropriate treatment. In those cases where hereditary syphilis is evident or suspected, specific treatment is demanded, but not of a vigorous kind. The simplest form of administration is bichlorid of mercury gr. $\frac{1}{60}$ and iodid of potassium gr. ij, after each meal. These remedies are well borne for many months. Inunctions of mercury are not usually called for except in very severe and well-pronounced cases. In the practice of some surgeons they constitute the basis of treatment in the majority of cases. The patient should be encouraged to go out of doors as much as possible, protecting the eyes with blue or gray glasses. Recently subconjunctival injections of bichlorid of mercury have been advocated quite strongly in certain quarters, as have those of normal salt solution, used in the same manner. The severe pain which has been found to accompany their employment is a great bar to their general use.

Results of Corneal Inflammation.—*Opacities of the Cornea.*—The outcome of an inflammation of the cornea as regards its *restitutio ad integrum* of transparency depends largely upon whether it is of the destructive form or not. A pannus or interstitial keratitis can continue for months or even years, and yet the cornea clear up almost perfectly, provided there has been no loss of substance replaced by cicatricial tissue. But even in the interstitial form there can be an organization of the effused material, taking on the character of connective tissue, which does not become transparent. Indeed, in the most favorable cases there are always fine streaks of opacity to be discovered by oblique illumination and the magnifier (see page 146).

Where there has been any considerable loss of tissue the rule is for an opacity to remain, the cicatricial material which replaces the lost corneal tissue never becoming transparent. The presence or activity of the corneal epithelium seems to exercise a favorable influence on the reproduction of the clear corneal substance. The clearing up of the opacity proceeds from the periphery toward the center.

Opacities have always been classified, according to their intensities, into *nebulae* or *maculae*, the slighter forms, and *leukomata*, the denser forms. When after a perforation of the cornea there is prolapse of the iris, with adhesion to the wound, we have the condition known as *adherent leukoma*.

The amount of damage to perfect vision caused by an opacity depends largely upon its situation, and to some extent upon its density. A small, sharply-defined, dense opacity over the pupil, however, will disturb vision less than a thinner one, which allows a greater amount of light to go through, but diffuses it more.

The course and final condition of a corneal opacity depend largely upon the age of the patient and the depth of the destructive process. In young people the chances of a clearing up are much better than in elderly ones, and the smaller and more superficial the ulcer the greater the probability of an ultimate clarification.

Treatment.—The treatment of corneal opacities is directed to an assistance in the absorption of the effused material. This requires usually some means which increases temporarily the vascularization of the part and stimulates the absorbents. Insufflation of finely-powdered calomel once a day is an old remedy. Another form of mercury much used is the yellow amorphous oxid, gr. j ad ʒj of cosmolin—"Pagenstecher's ointment"—a small bit to be rubbed under the lids once a day or every other day (*massage of the cornea*). Turpentine oil moderated with sweet oil has been used for the same purpose. In fact, everything which increases the blood-supply of the conjunctiva has been used, and with some show of success. The value of

the constant current of *electricity* applied to the cornea for this purpose has doubtless its basis in the same quality.

The attempt to remove opacities by operation is of course futile, since the removed tissue will be replaced by cicatricial tissue, except in those cases where the trouble is limited to the epithelial layer, as where there are deposits of lime, lead, etc., and in some cases of superficial pannus.

For cases of total leukoma of the cornea or large central opacities covering the pupil, with no room for an artificial pupil at the periphery, *transplantation of a portion of the cornea of rabbits* or other animals was first suggested by Reissinger in 1824, and revived by von Hippel in 1876. It cannot be said, however, that any brilliant permanent success has followed the attempts made thus far.

In case of leukoma adherens it may be necessary to loosen the iris from its adhesion to the cicatrix for optical purposes, or to free the eye from a source of constant irritation. An iridectomy is often called for when the opacity covers the pupil, even when there is no incarceration of the iris, for optical purposes.

In permanent opacity the disfiguring appearance can be much mitigated by the process of *tattooing* the white spot with India ink.

Changes in the Form of the Cornea.—While inflammations of the cornea may subside without any change in the form of the cornea, even when a considerable opacity remains, in a large number of cases, and especially in those where there has been a considerable loss of tissue or even long-continued infiltration, the original shape is seldom retained, and sometimes the change is enormous. This alteration may be in the manner of *flattening*—or of *bulging*—*staphyloma*.

(1) *Flattening of the cornea* most frequently follows upon total destruction or large losses of the corneal tissue, and especially in those cases where the uveal tract has been involved and the nutrition of the eye interfered with, accompanied by reduced tension of the eyeball. The iris is found in such cases plastered against the posterior wall of the remnant of the cornea, some portion of which may still be transparent. The flattening may be of any grade, from that discernible only by means of the ophthalmometer to that associated with a more or less complete atrophy of the eyeball.

(2) *Bulging of the Cornea.*—*Staphyloma* has various qualifying terms, denoting special characteristics. It may be *partial* or *complete*, *conical*, *globose*, or *racemose*, the latter name signifying a number of small protrusions linked together around the periphery of the cornea. A general enlargement of the eyeball (*hydrophthalmos*) (Fig. 214) is very often associated with these conditions and always indicates the participation of the iris and choroid in the inflammatory process. The iris may be attached to it either partially, as in *adherent leukoma*, or completely, as in some forms of *keratoglobus*.

All staphylomata indicate an increased tension of the eyeball at some time. The structure of a staphyloma is by no means uniform. Its walls may be thin or very thick, and sometimes the apex undergoes ulceration or degeneration of the calcareous or colloid form; and it is always liable to attacks of inflammation.



FIG. 214.—Hydrophthalmos after ophthalmia neonatorum: c, cornea; o n, optic nerve. (From a patient in the Children's Hospital, Washington.)

Treatment.—The therapeutics of staphylomata is preventive and surgical.

The former is applicable only during its stage of formation, when a pressure bandage should be applied to support the weak tissue. Paracentesis, sometimes repeated, by lessening the intraocular tension, removes an important factor in its production. Eserin can be used for the same end.

When a staphyloma has become so large as to be unsightly, or is a source of annoyance or pain, surgical interference of some kind is the only remedy: enucleation of the eye, abscission of the staphyloma, or evisceration.

Enucleation should be avoided when possible in children, among whom staphyloma so frequently occurs as a consequence of conjunctivitis neonatorum. The presence of the eyeball seems to be necessary to the proper development of the orbit, and an artificial eye is difficult to adapt to very young children. In cases of excessive hydrophthalmos the operation of evisceration finds its best field of application. Evisceration, with the introduction of a glass ball within the sclera (Mules's operation), gives an excellent support for an artificial eye (see page 572).

(3) *Cystoid Cicatrix.*—The condition of union between the tissues at the scleral border in some cases of adherent leukoma can be such as to form a circumscribed cystic elevation the walls of which may give way at times, discharging the contents of the aqueous chamber—the so-called *cystoid cicatrix*; or the opening may not close at all, constituting a *fistula*, through which the aqueous humor constantly leaks, sometimes under the conjunctiva, causing a *chemosis pallida*. Similar phenomena may arise after the operation of iridectomy.

These conditions are usually very rebellious to treatment, which is for the most part surgical, consisting in cauterization, the formation of conjunctival flaps over the parts, or cutting away a part of the walls of the cyst and procuring a firm adhesion between the edges of the wound. An iridectomy sometimes helps much.

(4) *Astigmatism.*—The changes in the form of the cornea are commonly so irregular (*irregular astigmatism*) that it is not possible to correct the optical defect by any form of lens in such manner as to improve vision materially. Changes are occasionally so regular, however, as to allow this to be done, and here the ophthalmometer becomes a valuable aid in diagnosis. With the suggestion afforded by this examination it is often possible to double or treble the visual acuteness (see also page 231).

When the intraocular pressure is reduced to any considerable degree the cornea feels the diminished tension, and manifests it by an altered curvature, sometimes in the nature of *wrinkling*. This is very apparent in many forms of atrophy. In cyclitis associated with reduced eye-tension it is nearly always demonstrable by the ophthalmometer, or Placido's disk. Fig. 215 gives the corneal reflection of Placido's disk in such a case. The cornea resumed its normal shape when the tension was restored.

Sclerosing Keratitis.—A special form of corneal opacity is associated with long-continued *scleritis* and *irido-choroiditis*.

It begins in the former case as a triangular bit of bluish-white tint, with its base on the sclera, its apex toward the center of the cornea. The change is interstitial, the epithelium seldom undergoing any alteration. When following long-continued inflammation of the uveal tract, with depressed nutrition of the eyes, the opacity sometimes extends as a band wholly or partially around the corneal circumference, as shown in Fig. 216, taken from a case under the author's own observation. Baumgartner and Berlin have found that the corneal tissue has undergone fatty and hyalin degeneration with what appears to be in some instances adenoid tissue.

Treatment is of no avail, though the galvano-cautery applied to the base of the lesion has been recommended.



FIG. 215.—Wrinkling of the cornea; reflection of Placido's disk.

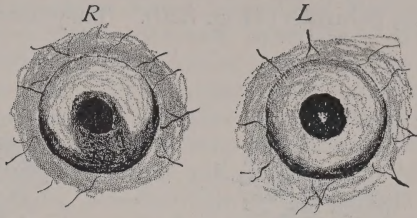


FIG. 216.—Sclerosing keratitis in both eyes from irido-choroiditis (author's case).

Ribbon-shaped Keratitis (*Primary Transverse Opacity of Cornea; Zonular Opacity; Keratitis Bandelette*).—This is a rare form of corneal opacity, not due to an inflammation of the cornea itself, but associated with or following some kind of ocular malnutrition, caused by irido-choroiditis, glaucoma, or a gouty tendency.

The lesion is situated directly in the palpebral aperture, where the cornea is most exposed, and consists of finely punctiform opacities under the epithe-

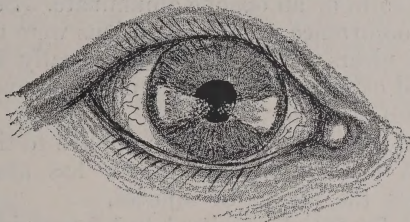


FIG. 217.—Keratitis bandelette (after von Graefe).

lium of the cornea. It begins sometimes on one side, sometimes on the other, leaving a small area of clear tissue at the periphery, and progresses steadily toward the pupil, over which the two bands usually meet in time (Fig. 217). Some cases have been observed in which it began in the center. Both corneae are liable to be affected in time. It occurs mostly in men. After the epithelium is removed the deposit can be flaked off, leaving, as a rule, clear cornea beneath. The deposit is either the phosphate or carbonate of lime. Its removal in this manner is the only treatment. Atropin should be avoided in such eyes, on account of their tendency to glaucoma.

Striped Keratitis.—A peculiar form of opacity of the cornea is sometimes noticed after cataract extraction, but has been observed also after other forms of injury or inflammation of the cornea. It consists of fine, straight stripes $\frac{1}{2}$ to 1 mm. in width, focussing toward the seat of injury. The intervening corneal tissue may be comparatively clear, in which case the lines will appear as grayish stripes against the darker background of the iris (Fig. 218). There may be two or more sets of lines crossing each other, making a sort of panel figure (Fig. 219).

They were once thought to be dilated by lymph-channels (Becker, Reck-

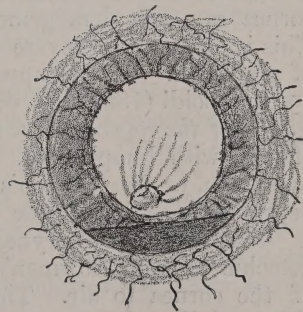


FIG. 218.—Striped keratitis with ulcer and hypopyon (after Schirmer).

linghausen) or infiltration of the large nerve-canals (Alt). They are caused, however, by a folding of the membrane of Descemet, due to a shrinking of the corneal tissue in cicatrization or its unequal swelling in infiltration (Mull, Hess, Schirmer) (Fig. 220). They usually disappear, but traces of them may



FIG. 219.—Panel-like opacities of the cornea (after Schirmer).



FIG. 220.—Section of the cornea showing the folds of the membrane of Descemet in panel-like opacity of the cornea (after Schirmer).

remain in the form of *geometrical figures* (Fridenberg). The folding of Bowman's membrane may give the same appearance.

Corneal Opacities due to Metallic Deposits.—The salts of lead coming in contact with the albumin of the cornea denuded of its epithelium are sublimated in the form of an opaque albuminate. Such deposits were of much more frequent occurrence when lead lotions were used more commonly than now in corneal ulcers. The epithelium usually forms over it. The deposit can be scraped off after the epithelium is removed, leaving usually a moderately clear cornea beneath.

Nitrate of silver also leaves a stain when applied to the substantia propria for a long while. A brilliant metallic luster has also been observed in opacities of the cornea the results of injuries.

Arcus Senilis.—An arc of opacity 1 to 1.5 mm. in width is very commonly seen at the base of the cornea in old people. It may entirely circle the cornea. There is usually a narrow strip of clear cornea between it and the sclera. It is sometimes met with in comparatively young persons. In the negro race it is usually very pronounced. It is a colloid degeneration of the superficial layers of the cornea. When incised it heals as readily as normal corneal tissue.

Transient Corneal Opacities.—Sudden and severe pressure on the cornea causes a derangement of its fibers which impairs its transparency. This is observed in severe blows directly on the cornea and in acute attacks of glaucoma. This disappears in a short time when the pressure is relieved.

Rampoldi (1881) has described a temporary form of opacity due to *infiltration of the corneal tissue with lymph*. It occurs in anemic persons or those affected with lymphatism. It may extend to the anterior chamber, forming hypopyon, or into Tenon's capsule. It may be called up or increased by a dependent position of the head.

Cocain causes a dryness and opacity of the epithelium, and even its detachment from Bowman's membrane, when applied too long with exposure of the cornea to air. The corneal epithelium in old glaucoma is nearly always dull and irregular.

Blood-staining of the Cornea.—A number of cases have been observed after traumatism in which the cornea has been infiltrated with blood; it is of a chocolate or greenish-brown color at the central parts, passing off into a reddish tinge at the periphery. The appearances closely resemble those of an amber-colored lens dislocated into the anterior chamber. The hema-

toidin deposited in the substantia propria, which gives this color, is absorbed very slowly, at least two years elapsing before its entire disappearance.

Keratitis Nodosa.—When the poisonous spines of certain caterpillars get into the eye, they set up an inflammation which is peculiar in that it is in the form of nodules which very much resemble tubercles. While more commonly found in the conjunctiva, the nodules occur also in the cornea, and pass sometimes into the iris. They never break down and discharge, but in time disappear by absorption (see also page 296).

No attempt should be made to excise the nodes from the cornea. They should be treated as secondary keratitis with heat and atropin.

Keratitis Punctata (*Aquo-capsulitis*, *Descemetitis*).—Small whitish deposits are observed on the posterior surface of the cornea in that form of iritis known as *serous iritis*, and have been considered by some authors as a form of iritis or irido-cyclitis. As the anterior surface of the iris and the posterior surface of the cornea are lined by a continuous layer of endothelial cells, converting, in fact, the anterior chamber into a closed or serous sac, there is some ground for this view; and in these cases, almost without exception, both cornea and iris are involved, sometimes, however, one more than the other. In some instances there is a marked plastic iritis accompanying or following the appearance of the dots in the cornea. Though the dots are usually arranged in a pyramidal shape, base down, they are often irregularly placed (Fig. 221). The deposits vary in size from a millimeter or so in diameter to a microscopic point. They consist of inflammatory exudate with a quantity of endothelial cells (Fig. 222). Snellen, Jr., is reported to have found a microbe in the deposits, but this observation has not been confirmed by others. The exudate is sometimes found in the iris angle and in the choroid. Oblique illumination and a magnifier are often necessary to determine its presence in the cornea. A general haziness of the

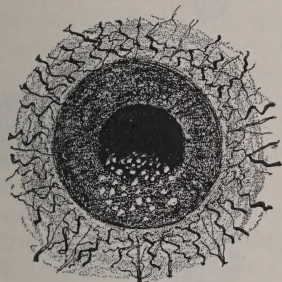


FIG. 221.—Descemetitis or keratitis punctata.

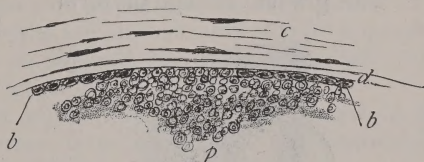


FIG. 222.—Deposit on the posterior surface of the cornea in punctate keratitis: *b*, endothelial cells; *c*, cornea; *d*, Descemet's membrane; *p*, deposit of round-cells (after Fuchs).

cornea or a limited part of it is manifest on illumination of the fundus with the ophthalmoscope. Usually there is no pain, the pupil is commonly somewhat dilated, and the intraocular tension slightly increased. Vision is usually much impaired.

Treatment.—Atropin must be avoided unless there is an active plastic iritis. The progress of the disease is usually very slow, months sometimes being required for the disappearance of the deposits. Mild doses of bichlorid of mercury, continued for a long while, seem to be followed by better results than any other therapeutics.

Non-inflammatory Changes in the Form of the Cornea.—Changes in the form of the cornea from the normal—which is really that of a triaxial ellipsoid, but not very markedly departing from that of a sphere—are known as *astigmatism*. Those changes which influence the optical properties of the eye that can be neutralized are treated of in the chapter

on Refraction. These forms usually are congenital, and remain unchanged during life.

There are other forms, however, which appear to be acquired, though not associated with any inflammatory affection. They are usually classed under the general heading of *Keratoconus* or *Conical Cornea*, from the fact that they always assume a form approximating that of a cone. The cone, however, is generally quite irregular. One case has fallen under the author's observation in which the curve of the vertical meridian was such that in the upper part of the pupil there was myopic astigmatism, and in the lower half hyperopic astigmatism. The apex of the cone is not always in the center of the cornea.

Except in a few cases, perhaps, keratoconus is not congenital, but begins to develop usually about the seventh or eighth year, though often later, reaching its climax not long after the establishment of puberty. Women are more often affected than men. The appearance of a well-marked case is shown in Fig. 223.

When less pronounced the abnormal curve cannot be detected by simple inspection, but is easily made manifest by the keratoscope (Placido's disk, see page 145). This is held in front of the eye or attached to the ophthalmometer of Javal, and its reflection on the cornea at its different parts observed. Instead of being approximately circular at the center, as it should be in the normal cornea, it has some modification of the appearances shown in Fig. 224.

Illumination of the fundus, as in examination by the "shadow test," shows, instead of a uniform reddish tint of the pupillary area, a dark spot, usually crescentic in form, in the red area, which changes with each movement of the mirror or eye.

The gradual change of form



FIG. 223.—Keratoconus. Pronounced case.

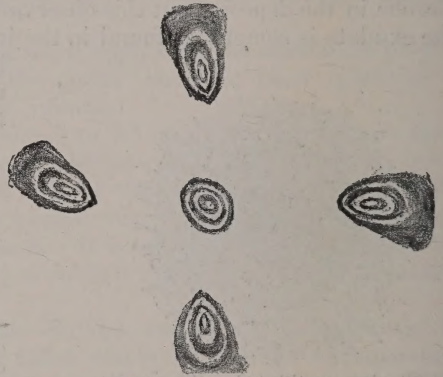


FIG. 224.—Keratoscopic appearance of keratoconus (Placido's disk of rings). Irregularly oval at apex of cornea; drawn out into pointed arches at the periphery.

of the cornea is due to a weakening of the corneal tissue and an increase of the intraocular pressure. The determining cause is not known. Vision is much reduced, and, since both eyes are nearly always affected, though often in varying degree, these patients are always "near-sighted," though not necessarily myopic, having to hold all objects close in order to obtain large retinal images.

Treatment.—In many cases vision can be much improved by glasses, a certain amount of regular astigmatism being found by the ophthalmometer. The light coming through the sides of the cone is that generally used, and therefore, as a rule, plus cylinders are preferred. Raehlmann devised *parabolic* glasses to correspond to the corneal curve, but they have not been found of much practical use.

Surgical treatment in the way of flattening the cornea by the knife or a

trepine, or burning it away with caustics, promises better. The stenopaic slit is often of benefit in obtaining better outlines of objects, but the diminution of field and illumination are its drawbacks.

Morbid Growths on the Cornea.—Of benign growths, *fibroma* (Fig. 225) is the one most commonly found on the cornea. It may come on independently or it may develop on cicatricial tissue the result of a previous ulceration. There is a tendency to return after removal. *Papilloma* may also find its habitat here.

Malignant growths are usually, perhaps always, of the epithelial variety, at least at the beginning, and are commonly secondary to similar growths on the conjunctiva or sclera. A few cases of *sarcoma* appearing primarily on the cornea itself have been reported. *Leprosy* may attack the cornea.

Congenital Defects of the Cornea.—The most common of these are *dermoid tumors* of various kinds (Fig. 226). Usually they are seated

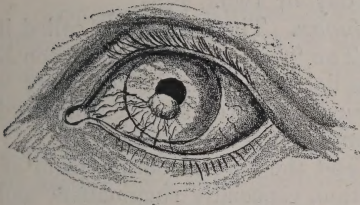


FIG. 225.—Fibroma of the cornea (after Falchi).

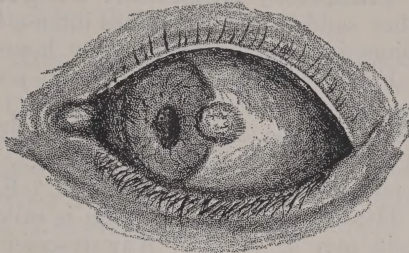


FIG. 226.—Dermoid of the limbus—colored woman aged twenty-one years (from the author's clinic).

on the corneo-scleral margin, and are sometimes associated with some other malformation of the eye, generally coloboma of the lid.

Congenital opacities are not common, but a number of cases have been recorded. They may be due to intra-uterine inflammation or to arrest of development: in the latter case the two eyes are apt to be affected in approximately the same manner. *Congenital staphyloma* has been described. It may be associated with a dermoid growth.

Microphthalmos is that condition in which the entire eye remains in a rudimentary state, and in which the cornea is reduced in all its diameters.

Megalophthalmos (see Buphthalmos, p. 385).

Sclerophthalmia is that condition in which, owing to an imperfect differentiation of the sclera and cornea, the former encroaches on the latter, so that only the central part of the cornea remains clear. Sometimes only the upper half of the cornea is affected.

DISEASES OF THE SCLERA.

Episcleritis.—The most common form of scleral inflammation is that known as *episcleritis*, in which the subconjunctival tissue and superficial layers of the sclera are conjointly affected.

Symptoms.—Episcleritis manifests itself as an ill-defined spot of infiltration with an elevation of 1 to 1.5 mm. Its seat of election is from 2 to 6 mm. distance from the corneal edge and to the outer side. Its color is not of a pure deep red, but rather of a bluish or violet hue; it is not movable on the ball and is more or less sensitive to touch. The conjunctival vessels leading up to it are congested, but the remaining part of the scleral surface is usually clear. There are in most cases considerable photophobia and lachrymation. The

disease is tedious in its course, sometimes running for several weeks, and is subject to recurrences, and it may be at different localities on the ball.

A rheumatic or gouty diathesis usually lies at the bottom of it, but it also occurs from exposure and with scrofula and menstrual disorders.

Treatment.—General treatment must be along these etiological lines. Large doses of salicylate of sodium often have a good effect on the pain and shorten the course of the disease; in some cases pilocarpin sweats are beneficial. Subconjunctival injections of bichlorid of mercury or physiological salt solution have been used with good effect. Scarification of the tissue has also been recommended. Heat is the best local remedy, and may be used in the form of hot bathing or the Japanese hot box. As iritis has been known to develop during its course, atropin should be used at the height of the disease; but if there is no iritis, pilocarpin or eserin locally (gr. $\frac{1}{12}$ —gr. $\frac{1}{4}$), combined with cocain, is most useful. Galvanism has been recommended.

Transitory Episcleral Congestion.—This is the name given to a rather sudden and sometimes intense hyperemia of the sclera and overlying conjunctiva, lasting from a few hours to a day or two.

Fuchs (1895) calls it *episcleritis partialis fugax*. The author has called it *a vaso-motor dilatation of the vessels* (1892). The “hot-eye” of Hutchinson is probably of the same nature. The affection is liable to recur for years, and is not attended with danger to vision. It is usually painful and accompanied by photophobia and lachrymation. Exceptionally it occurs in children.

Heat for the relief of pain is called for, and the careful employment of cocain may be of use. Any dyscrasic condition, especially rheumatism and gout, must be attended to.

Deep Scleritis.—Inflammation of the sclera as a whole is very uncommon independently of a panophthalmitis. But the deeper layers of the sclera can become inflamed, though this is seldom the case, except in connection with inflammation of the underlying uveal tract. A very common instance of deep scleritis is what is known as *sclerotico-choroiditis posterior*, nearly always found in high grades of myopia (*posterior staphyloma*) (see page 221). The inflammation affects the anterior part less commonly, when it is known as *anterior scleritis*.

The disease nearly always begins in the uveal tract, and the sclera, becoming soft, yields to the intraocular pressure and bulges, causing a *ciliary staphyloma* which may be *equatorial*. There may be more than one staphyloma, and they may invade the edge of the cornea. They are bluish in color from the pigment showing through the thin scleral tissue. There are considerable congestion, lachrymation, and photophobia, the intensity of the symptoms depending upon the amount of ciliary or iritic involvement.

In a less intense form the disease may be chronic and last for years, with recurrences. Rheumatism, gout, and syphilis (*gummatous scleritis*) are to be counted as its causes, and its general treatment must be directed to the correction of the demonstrated or suspected dyscrasia. Locally, heat, atropin, and, when the staphyloma is thin, a pressure bandage, are indicated.

Tumors of the sclera generally are extensions from the neighboring conjunctiva or cornea. The *benign* ones are fibromas enchondromas, and the *malignant* ones are epitheliomas or sarcomas.

Melanosis of the sclera is usually congenital, and these dark spots are common in the negro race. Melanosis may occur in Addison's disease.

Abscess of the sclera has been observed. It is usually the result of injury, and seldom idiopathic. One or two cases of *osseous degeneration* of the sclera have been reported.

DISEASES OF THE IRIS, CILIARY BODY, AND CHOROID; SYMPATHETIC INFLAMMATION AND IRRITATION.

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DISEASES OF THE IRIS.

Congenital Anomalies of the Iris.—Heterophthalmos is the condition where the irides differ in color. One iris may be brown and the other blue. These differences in color may exist in the same iris, so that one part will have a distinctly different nuance from its immediate surroundings. The pupillary margin of the iris may be quite different in shade from its peripheral portions. Minute areas differing in color are not infrequently seen, and sometimes these areas assume the form of elevations upon the surface of the iris. (See also page 147.)

Persistent pupillary membrane is the remains of the membrane which occupied the pupillary field during fetal life, and, according to Manz, is part of a layer of tissue of the head-mesoderm containing vessels and surrounding the secondary ocular vesicle; this layer becomes differentiated into a posterior portion, the *choroid*, and an anterior portion, the *membrana pupillaris* (see also page 23). What is seen of this membrane consists only of a number of fine (usually pigmented) threads, anastomosing with one another and arising from the anterior surface of the iris and near the free border of the latter; in other words, from the *circulus iridis minor*. The threads are never present in any considerable number, for rarely more than ten or twelve, and usually less, are seen. These threads after converging pass across the posterior chamber and come to a point on the anterior capsule of the lens, this point being frequently

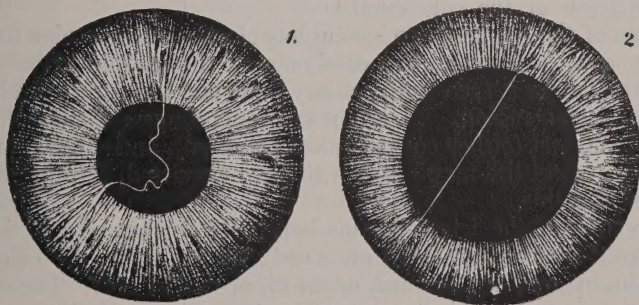


FIG. 227.—Persisting pupillary membrane: 1, pupil contracted; 2, pupil dilated (Wickerkiewicz).

marked by a pigment speck, or they may reach the anterior capsule at different points. It is seldom that the threads spring from all sides of the pupil, but usually from one or two points. They do not invariably pass across to the

lens capsule, but after running out for quite a distance into the pupillary field they return to the iris to be inserted near their point of origin.

A persistent pupillary membrane is not infrequently confounded with the *synechiae* which remain after an iritis, but the oblique illumination will reveal the true nature of the affection. Moreover, the pupil dilates symmetrically to its full extent in the former condition, while in the latter case irregularities may be seen in the contour of the pupil (Fig. 227).

According to Fuchs, persistent pupillary membrane is of comparatively frequent occurrence in the new-born. Jacob and others¹ have succeeded in injecting these threads soon after birth, thus showing that the threads are vessels. As is well known, these threads undergo atrophy and are obliterated in the ordinary course of events. This affection is not often seen in both eyes.

The disturbance in vision is slight, depending upon the number of threads and the extent to which the anterior capsule is involved. The condition practically never demands operation, though von Graefe resorted to operation where the vision was $\frac{1}{100}$.

Coloboma of the Iris.—This is one of the most frequent malformations met with in the eye. It consists of an oval-shaped fissure or gap in the iris, which has the effect of prolonging the pupil in a direction usually downward and a little inward. A *complete coloboma* is where the fissure separates the iris in its entire breadth, and an *incomplete coloboma* is one where the cleft stops short of the ciliary border of the iris. The coloboma is usually smaller at its ciliary end, though the reverse of this has been observed quite often, in such cases the borders being almost parallel instead of convergent. There is often seen just within the pupillary end of the fissure a slight constriction which gives to the pupil and coloboma together the appearance of a keyhole. Sometimes the pupillary ends of the fissure are bridged over by a slender membrane or a thread, forming what has been described as the *bridge-coloboma*. In those cases where a thread has been formed the latter is supposed to be the remains of a pupillary membrane.

Coloboma is generally bilateral, though Manz is of the opinion that the affection is more frequently monolateral. In the latter variety the other eye often exhibits peculiarities, either in the color of the iris or in the shape of the pupil.

The congenital coloboma is distinguished from the artificial coloboma by the presence in the former of the sphincter, while in the latter, *i. e.* in an artificial coloboma (as after an iridectomy), the sphincter has been excised along the margin of the coloboma.

Coloboma of the iris is due to incomplete closure of the ocular fissure (page 22), and along with this condition coloboma of the choroid often exists, and sometimes the fissure is seen in the ciliary body and lens, and even in the optic nerve and macular region. It is not infrequently associated with microphthalmos and cataract (either congenital or acquired), and other fissures which usually close in fetal life may be seen to have persisted, forming harelip and coloboma of the lids.

The direction of the iris-coloboma is usually downward and inward, but exceptions to this rule have been observed; for example, the coloboma may be up and in, up and out, inward, outward, or downward. The accompanying illustration is from a photograph (Fig. 228) of one of the very few cases reported where the coloboma was directed upward. The case was first put on record several years ago by Theobald.²

¹ *Med.-Chirurg. Trans.*, London, vol. xii. p. 515.

² *Trans. Amer. Ophthalm. Soc.*, vol. v. p. 99.

The possible explanation of the unusual locations for the coloboma is that the ocular vesicle made a quarter or half a revolution about its long axis.

No satisfactory explanation has been offered for the failure of the ocular fissure to close. Some regard it as simply an instance of retarded development, while others think that inflammation must have played a part in



FIG. 228.—Coloboma of the iris with the coloboma directed upward.

producing the defect. The rôle played by heredity in this affection is certainly worthy of consideration.

Irideremia, or Aniridia.—This is a condition in which the iris is either completely absent or in which only one or more segments remain. When the irideremia is *complete*, it is possible to see the entire lens, which is often so exposed that even when cataract is present there is good sight, there being space enough between the edge of the lens and the ciliary processes for the light to pass through. When the irideremia is *incomplete* there is an absence of the iris at certain points, so that only a segment remains here and there. The narrow rim of iris which is sometimes seen just behind the corneo-scleral junction all the way around is not incomplete irideremia.

Myopia, hyperopia, astigmatism, and amblyopia are often present in irideremia; also a cloudy cornea. Cataract is not infrequently found associated with it, generally in the form of the anterior or posterior polar cataract, which in these cases is usually congenital. It should be said, however, that eyes affected with irideremia are peculiarly prone to cataract, so that this last-named condition may make its appearance any time after birth.

Irideremia is almost always a binocular affection. As regards its etiology, heredity undoubtedly plays an important rôle. The affection is clearly one of retarded development.

Under this head should be mentioned those cases where there is a narrow rim of iris springing out all the way around in front of the periphery of the lens. This condition is one step removed from irideremia, and is really an instance of *rudimentary development of the iris*.

The wearing of dark glasses in irideremia sometimes gives great relief, or spectacles with a stenopaic slit.

Ectopia Pupillæ (*Eccentric Position of the Pupil; Corectopia*).—The normal situation of the pupil is not exactly in the center of the iris, but a little below and to the inner side of the center. Sometimes the pupil is found eccentrically located. It may be near the normal site, and again it may be remote from this situation, as, for instance, near the ciliary border. Such a pupil is long-oval in shape, rarely, if ever, round. The most usual location is downward and inward, though it has been observed upward.

We are completely in the dark as to the origin of ectopia. Some authors believe that the condition is closely allied in its origin to coloboma of the iris, and give as a reason that the misplacement is nearly always at the most frequent location for coloboma. Others hold the opinion that ectopia pupillæ is due to a lack of development of the muscular elements of the iris at a certain point, with possibly an excessive development of the same elements at a point opposite, the effect being to pull over the pupil to the stronger side.

A not infrequent complication of ectopia pupillæ is a dislocated lens.

Dyscoria (*Faulty Pupil*).—This is a condition in which the pupil is faulty or irregular in shape, and is usually brought about by the presence of little excrescences on the margin of the pupil. These excrescences may attain such a size as even to meet at different points in the pupillary field, leaving only here and there small openings—a condition called *corestenoma congenitum* (Von Ammon), also *polycoria*. The condition is not infrequently seen in horses. The nature of these excrescences is not known.

Motor Disturbances of the Iris.—The movements of the iris consist in dilatation and contraction of the pupil, and a motor disturbance of the iris means an affection which is characterized by some alteration in the size of the pupil.

Mydriasis and Myosis.—An alteration in the size of the pupil may show itself in either persistent dilatation (*mydriasis*) or contraction (*myosis*) of the pupil, or in a condition in which the pupil is incessantly dilating and contracting (see also page 149).

Hippus.—This condition is one which is characterized by constant dilatation and contraction of the pupil. It is really a clonic spasm of the sphincter pupillæ (see also page 151).

Iridodonesis (*iris tremulans*) is a tremulous movement of the iris whenever the eyeball is moved, and is due to loss of, or defective support of, the iris. The condition is often seen after cataract extraction, especially the simple extraction. It is observed in cases of fluid vitreous where trophic changes have taken place in the lens and the latter has become smaller; in congenital cataract where the lens has undergone calcareous degeneration and shrinkage; and, finally, in luxation of the lens. Although not a functional motor disturbance of the iris, iridodonesis is conveniently referred to in this place.

Hyperemia of the Iris.—Hyperemia of the iris is characterized by a change in the color of the iris, which assumes a yellowish-red shade, so that a blue or gray iris appears greenish, and a brown iris will have in it a suggestion of red. In dark eyes, however, this discoloration is not so marked as it is in eyes of the blond type. As a rule, this symptom is more noticeable in cases of hyperemia than in conditions of marked iritis, where the iris is the seat of structural changes, and where the aqueous humor is filled with the products of the inflammation. De Wecker remarks upon the frequency with which a similar discoloration of the iris occurs in severe subconjunctival

hemorrhages, and he thinks that in such cases it is due to the fact that either the iris or the aqueous humor has become infiltrated with the soluble coloring matter in the blood.

In cases of *chronic hyperemia* there is a discoloration of the iris due to changes in the pigment-cells, and a complete disappearance of the pigment at the pupillary border, which becomes ragged and notched. These changes are only seen after the hyperemia has existed for a long time. The same appearance of the iris is seen in very old people without coincident hyperemia, and is attributable to *senile changes in the iris*.

In hyperemia of the iris the pupil no longer reacts as it does normally, but remains more or less contracted; and this sluggishness of the pupil is even noticeable when atropin is used, several instillations of the mydriatic being required to secure full dilatation. One of the first symptoms of hyperemia of the iris is the *pericorneal congestion*, which is of the character peculiar to affections of the uvea and cornea, and consists of a number of very fine vessels situated in the episcleral tissue and running out in straight lines from the corneal margin, forming, as it were, a sort of fringe to the latter structure.

Etiology.—Hyperemia of the iris often leads to inflammation of the iris; indeed, it might be said that every iritis is preceded by a stage of hyperemia. The cause of hyperemia, then, may be sought for in anything which will produce an iritis. Inflammation in structures anatomically connected with the iris may bring about hyperemia in the latter; for instance, keratitis, particularly the phlyctenular form. A foreign body on the cornea or the effect upon the cornea of a caustic agent will produce very quickly hyperemia of the iris. Inflammations of the choroid and ciliary body are fruitful sources of this phenomenon, and the same may be said of affections of the sclera; for instance, episcleritis.

Treatment.—Rest, dark glasses, and the instillation of atropin. An investigation into the cause of the hyperemia will suggest the proper general treatment.

Iritis (*Inflammation of the Iris*).—The two most frequent causes of iritis are probably syphilis and rheumatism, and yet there is no constant and distinctive symptom by which we can infallibly recognize which diathesis is present. Symptoms which one author regards as characteristic of syphilitic iritis are mentioned by another as belonging also to rheumatic iritis, and *vice versa*. If all cases of iritis of syphilitic origin presented the characteristic formation of nodules, it would be reason enough for making syphilitic iritis one grand division of the subject; but, in spite of the fact that by far the majority of cases of iritis are due to syphilis, the appearance of nodules (macroscopically) is the exception rather than the rule.

Iritis of rheumatic origin is supposed by some authors to be peculiar in its great tendency to recurrence, but it is doubtful whether iritis of this type possesses greater liability to recur than the syphilitic form. Exception might be made of those cases of iritis seen with arthritis deformans, especially in young persons. In such cases the prognosis is bad, owing to the persistency of the constitutional affection. Iritis of syphilitic origin is constantly encountered where recurrent attacks have been making their appearance for years. In both syphilis and rheumatism iritis will be apt to reappear so long as the constitutional disease is present. Inasmuch, then, as it confuses the subject to treat it from a diathetic point of view, the old divisions of iritis—*plastic*, *serous*, and *parenchymatous*—although by no means free from objections, will be followed.

Objective Symptoms.—The disease in general is characterized by all the symptoms which have been described in connection with hyperemia of the iris, except that these symptoms now are more intense and are associated with an exudate. This exudate may be thrown out from the posterior surface of the iris and into the posterior chamber, causing adhesions between the anterior surface of the lens capsule and the posterior surface of the iris (*posterior synechia*). Sometimes, though not often, there is complete adhesion of the posterior surface of the iris to the anterior surface of the lens—a condition known as *total posterior synechia*.

The exudate on the posterior surface of the iris is found in the pigmentary layer, and the region where the synechiæ are most apt to occur is about the pupil, for here the iris is in contact with the lens-capsule. The exudate may be found also on the anterior surface of the iris, and it may be thrown out into the aqueous humor, and, dropping to the bottom of the anterior chamber, form a *hypopyon*¹; or it may be found in the cornea in the shape of small points situated in the membrane of Descemet (so-called *keratitis punctata*, see page 327). Sometimes the exudate is poured out into the pupillary field, in which case it usually proceeds from the anterior surface of the iris. In such cases the iris reflex is lost. Finally, the exudate occurs in the substance proper of the iris, and shows itself by swelling of the iris, which is often thrown into folds.

It may be stated broadly that when the exudate is mostly confined to the region about the pupil we are dealing with *plastic iritis*; that when the exudate is found in the anterior chamber and upon the posterior surface of the cornea we are dealing with *serous iritis*; and, finally, that when the iris is swollen and thrown into folds we have before us the *parenchymatous* variety of the disease.

According to De Wecker, neither the plastic nor the serous form of iritis is apt to leave lasting changes in the iris, while in parenchymatous iritis there is more or less obliteration of vessels and disappearance of pigment.

Iritis Simplex or Plastic Iritis.—Pericorneal congestion is always present in this form of iritis, and its varying intensity offers good evidence of the grade of the disease. In very light cases of plastic iritis the pericorneal congestion may be so insignificant as easily to be overlooked, while at other times it may show itself in *chemosis*, though this is rare even in the most intense inflammations of the iris. The cornea does not participate, though on superficial glance this does not seem to be the case. Oblique illumination, however, will show that what at first sight seems to be a dulness of the cornea is nothing more than a loss of the iris reflex, due to the exudate upon the anterior surface of the iris and to the slightly cloudy aqueous humor. A cloudy aqueous humor is not a noticeable feature in this variety of iritis, while it is a condition quite characteristic of serous iritis.

The pupil is contracted and sluggish, and shows no response to the usual tests. This condition of the pupil often persists in spite of the use of a mydriatic, and frequent instillations will be necessary to get the same dilatation which ordinarily can be obtained by one instillation. The explanation of this must be sought for not only in the ciliary irritation, and in the diminished activity of the dilator fibers caused by their infiltration with inflammatory products, but also in the necessary loss of activity in a tissue which is inflamed and swollen; and, finally, in the presence of the exudates which bind the border of the pupil to the anterior capsule of the lens. These exudates

¹ Sometimes a gelatin-like mass is deposited in the anterior chamber, which, when it consolidates, resembles a dislocated lens. This is the so-called *spongy iritis*.

may be seen by oblique illumination. Several instillations of atropin will bring out strikingly the deformities in the pupil; those parts of the pupil which are not adherent will respond to the mydriatic, while the points which are bound down to the lens will remain fixed.

Sometimes the entire pupillary margin is adherent to the capsule of the lens—a condition known as *seclusion of the pupil*. This kind of synechia is not usually the result of one attack of iritis, but is found as a sequel of several recurrent attacks. At other times the pupillary field is completely filled with a mass of exudate, producing the condition known as *occlusion of the pupil*. If the adhesions are slight, they can be broken loose by the action of atropin, and when this is done small pigment-specks may be seen on the surface of the lens, marking the points where the iris was adherent.

Serous Iritis.—Instead of a plastic exudate, there may be an exudate, serous in character, containing solid elements, which are always to some extent deposited upon the posterior surface of the cornea. There seems to be an increased secretion of the aqueous humor, and the latter is quite cloudy. The deposits upon the membrane of Descemet are sometimes very fine, and are to be seen as small whitish or yellowish-white dots which can be brought out by oblique illumination or by examination with a strong convex lens (see Fig. 221). These deposits are sometimes found on the anterior capsule of the lens. Synechiæ are not as prominent symptoms in the earlier stages of this variety of iritis as they are in the plastic form, although they appear ultimately and contribute very materially to the grave prognosis.

Atropin, therefore, will not disclose irregularities in the contour of the pupil to the same extent as in plastic iritis, and frequently the pupil is symmetrically dilated, though never *ad maximum*. The pericorneal congestion is usually slight. The tension, as a rule, is elevated, due, no doubt, to the hypersecretion going on within the eye. The pupil by its dilatation shows the effect of this increased tension.

It is more than probable that in serous iritis the entrance to Schlemm's canal is blocked with exudate—a condition which of itself would be apt to bring about glaucomatous symptoms. As a rule, hypopyon is absent in serous iritis. Opacities in the vitreous body are very common, and degeneration of this part of the eye usually follows sooner or later. Ultimately, the inflammation affects the whole eye.

Parenchymatous Iritis.—In this form of iritis the inflammation attacks the iris tissue itself. Instead of an exudate on the anterior or posterior surface of the iris, the exudate is found within the iris. The swelling, which is always present, is often circumscribed, and produces an impression as though there were *nodules* within the iris. The masses of exudate are pigmented, and are found around the pupillary margin, often binding the iris to the anterior capsule of the lens. Sometimes these exudates find their way into the anterior chamber, and, settling at the bottom of the latter, form *hypopyon*; at other times they are thrown out into the posterior chamber. Even the pupil is sometimes filled with these yellowish masses. The appearance of the iris is dull, and pericorneal congestion is usually intense. There often may be seen the formation of little yellowish-red nodules traversed by blood-vessels, practically what is observed in the so-called syphilitic iritis, and designated *iritis papulosa* (Fuchs) when occurring in the secondary stage of syphilis; *iritis gummosa*, in the tertiary stage.

A typical parenchymatous iritis may be produced in rabbits by injecting a drop of a suspension of the *staphylococcus aureus* into the anterior chamber, the inflammation being attended with the formation of small elevations on

the iris and nodular masses at the pupillary border, not unlike the appearances visible in the same disease in man.

In parenchymatous iritis there is often present a pupillary membrane which stretches over the entire pupillary area. Sometimes a purulent infiltration of the iris (*purulent iritis*) occurs, with a deposit of leukocytes in the anterior chamber. Parenchymatous iritis, so long as it confines itself to the iris, may leave the eye unimpaired in its functions.

De Wecker calls attention to the peculiar nature of the *hypopyon* in these cases. It differs from the hypopyon seen in keratitis, because it is much thinner and changes its position with every movement of the head, and is remarkable for the rapidity with which it undergoes absorption, frequently disappearing in the course of a few hours.

Subjective Symptoms of Iritis.—While iritis may exist without pain (as is often the case in the serous form), as a rule this is a prominent symptom. The pain is not referred so much to the eyeball as to the temples and forehead and the neighboring regions supplied by branches of the fifth pair, and is of a boring character and apt to be more intense at night. The pain is not only the result of pressure upon the ciliary nerves by the products of the inflammation, but also the result of an actual involvement of these nerves in the inflammatory process. Pain, however, is no absolutely reliable index of the grade of an iritis. Plastic iritis, as a rule, is characterized by more pain than the parenchymatous form, yet one would be disposed to expect the opposite. Fournier,¹ among others, has called attention to the fact that parenchymatous iritis, in spite of the extensive anatomical changes present, is often associated with little or no pain.

Lachrymation and photophobia vary with the ciliary neuralgia. Visual disturbance is always present, and varies in degree with the clouding of the aqueous humor and with the extent to which the pupillary area is occupied with exudates. In serous iritis the disturbance in vision may be explained by changes in the vitreous body and choroid, and even in the optic nerve. Finally, such constitutional symptoms as fever and nausea have been occasionally observed, and a coated tongue is a frequent accompaniment.

Etiology.—The causes which give rise to iritis are *local* and *constitutional*. Among the first class are foreign bodies in the cornea, which have remained there for a considerable length of time; the careless and continued use of caustic agents; penetrating wounds of the eyeball; and swollen masses of lens-matter. Iritis may arise from an inflammation of the cornea, sclera, ciliary body, or choroid, in which cases iritis extends by continuity of tissue. Finally, iritis may arise from trouble in the other eye—sympathetic ophthalmitis.

Among the diatheses which give rise to iritis, *syphilis* stands easily first. Indeed, nearly 75 per cent. of all cases of iritis can probably be traced to this source. The iritis is generally of the plastic variety, although the parenchymatous form may occur. It shows itself generally in the secondary stage of syphilis, and when the parenchymatous form of the disease prevails there are often seen small nodules either at the margin of the pupil or at the ciliary border of the iris, and at these points there are usually synechiæ. When the nodules disappear there may remain in the iris atrophic areas. While the presence of these nodules probably justifies the surgeon in diagnosing the case as one of syphilitic iritis, it should be remembered that in the majority of cases of iritis, where a syphilitic origin is clearly demonstrable, apparently no nodules are present. The nodules may attain quite a large size, and several

¹ "Des Affections oculaires d'origine syphilitique," *Journal d'Ophthal. de Paris*, pp. 495-543.

of them may fill the anterior chamber, and, increasing in size, may burst through the envelopes of the eye. This termination is rare. *Hereditary syphilis* seldom gives rise to iritis, and when it does the subjects are usually young people, just as is the case with interstitial keratitis.

Rheumatism (articular) is another not infrequent cause of iritis. Two such cases the writer has in mind—one, a boy fourteen years old, who has not walked for four years, and who is completely disabled from articular rheumatism; the other, a young woman nineteen years of age, who has been confined to her bed for eight years. The girl has only light perception, her pupils being entirely bound down by adhesions, while in the case of the boy there is seclusion of the pupil in one eye, and the other eye possesses only sufficient sight to allow him to see large objects. Both these patients have had skilful treatment, which has availed but little, owing to the intensity of the constitutional affection.

It is doubtful whether the rheumatic diathesis gives rise to distinctive ocular symptoms, though some authors speak of the peculiarity of the episcleral and pericorneal congestion. As might be inferred, rheumatism of the character seen in the two cases just mentioned, when associated with iritis, would probably be the occasion of *recurrent* attacks of the eye-affection. In this connection it should be said that *gout* often gives rise to iritis.

Gonorrhea sometimes causes iritis. In such a case no doubt there is a general infection, although it is not at all probable that the gonococcus gets into the intraocular circulation, but its toxins reach the eye and there give rise to iritis. Inflammation of the knee-joint commonly precedes the eye-affection. When iritis is found as a result of gonorrhea, it shows a tendency to recur, and is frequently associated with a renewal of the pains and swelling in the joint.

Scrofula (*scrofulous iritis*) sometimes, but rarely, gives rise to iritis, and, as is the case with hereditary syphilis, the subjects are young persons. According to Fuchs, iritis in these cases is marked by the appearance of lardaceous-looking deposits or exudates, which seem to grow out from the sinus of the chamber. *Anemia* may be associated with an iritis of this character.

Relapsing fever (iritis in acute infectious diseases), *typhus* and *typhoid*, *small-pox*, *cerebro-spinal meningitis*, *pyemia*, and even *epidemic influenza* (grippe), have been known to cause iritis. Inflammation of the iris in *relapsing fever* is very tedious in its course. Iritis is occasionally caused by malaria (*periodic iritis*) and by irregularities of menstruation (*iritis catamenialis*).

Diabetes (*diabetic iritis*) is another very rare cause of iritis. In spite of the fact that hypopyon is often observed in this variety of iritis, the course of the disease is usually favorable.

Tuberculosis in other organs may give rise to iritis (*tuberculous iritis*), although such an origin is not often seen. Tuberculosis shows itself in the iris either in the form of grayish-red nodules or as a solitary tubercle resembling a neoplasm. Children are usually the subjects. While it is a very rare affection, its nature is well understood, for Cohnheim has produced the disease experimentally in rabbits by introducing small pieces of tuberculous material into the anterior chamber. The immediate effect of this operation is apparently negative, but within a month iritis sets in and the characteristic gray nodules appear. These increase in number till they fill up the anterior chamber, when (unless the animal dies) they may break through the coats of the eye. This is the *disseminated* form of the affection.

The little nodules are usually located at the pupillary margin. In man the disease is generally followed by a plastic irido-cyclitis and loss of the eye.

Tuberculosis of the iris also occurs as a *solitary tubercle*. This tubercle more often appears alone, though it may exist along with the nodules. When alone the symptoms of iritis can be absent—that is, for a certain period of its history—although iritis ultimately appears. It was regarded by von Graefe at first as a tumor, and described as such under the name of *granuloma*. Haab first demonstrated its true nature.

The *disseminated* form may occur in both eyes, but the *solitary* form has only been observed in one eye. In both varieties the eye is usually lost.

Mention may be made here of what has been called *recurrent iritis*, where the patient for months may be free of the disease and suddenly an outbreak will occur. Both eyes are usually affected, but rarely at the same time. Synechiæ are frequently left after an attack, and it has been thought that their presence determined subsequent attacks, but it is more than probable that some persistent constitutional affection (generally syphilis) is responsible for the recurrences. It has been observed that men more often than women are the subjects of this variety of iritis.

Traumatism is responsible for a number of cases of iritis. The injury may be accidental, or may be inflicted during the course of an operation, or occur as the result of an operation—*e. g.* after discission of the lens.

No time of life seems exempt from iritis, although it is exceptionally seen in children under ten years of age, and it is not often met with after the seventieth year. According to von Ammon and von Arlt, iritis is more frequent in men than in women.

Pathological Anatomy.—The iris is thickened and infiltrated with round-cells. This round-cell infiltration will be found marked along the blood-vessels. The exudate is composed of fibrin filled up with leukocytes and round-cells, and is generally more extensive upon the posterior surface of the iris. When found in the pupillary field the exudate is rich in pigment-granules, although this is the case to a certain extent everywhere. The coats of the blood-vessels are thickened and capillary hemorrhages are abundant. Masses of granular debris, the exact nature of which it is difficult to determine, are always present. In cases where seclusion of the pupil has occurred it will be found that the iris has undergone atrophy in those parts bordering upon the pupil. Where the entire posterior surface of the iris is bound down to the lens, sooner or later atrophy of the whole iris occurs, and it will be found that all that is left is a thin membrane, and here and there within its folds a clump of disintegrated cells. Sometimes there are scarcely any traces of the structure of the iris; even the sphincter has disappeared.

Diagnosis.—The character of the conjunctival congestion, the slightly turbid aqueous, and the sluggish pupil in iritis distinguish it from conjunctivitis. If the two irides are compared, the change of color of the affected iris, due to hyperemia, will be observed. In conjunctivitis the pain is burning in character, is referred especially to the lids, and is quite constant, while in iritis it is usually paroxysmal, is referred to the temples and brows, and often is more intense at night. Vision is never materially affected in simple conjunctivitis, while visual disturbance in iritis is the rule. Iritis may be distinguished from glaucoma (with which it is often confounded by the inexperienced) by the size of the pupil, which in the former disease is contracted, while in the latter it is dilated. The tension, while it may be elevated in iritis (particularly in the serous form), is not so as a rule. The tension in glaucoma is always elevated.

Prognosis.—This depends upon the cause and also upon the changes which have already taken place in the iris. If the pupil is completely dilatable with atropin, the prognosis may be regarded as favorable. The presence of numerous synechiæ, especially when one or more fail to yield to the action of the mydriatic, means often a recurrence of the iritis, although cases are not infrequently seen where two or three synechiæ have been present for several years, without recurrence of the iritis; and with good vision. Where there is either *seclusion* or *occlusion of the pupil*, an accumulation of aqueous often occurs in the posterior chamber, and leads to a bulging forward of the iris and ultimately to increased tension (*secondary glaucoma*). Where there is a total posterior synechia, the iris instead of bulging forward may be retracted at its periphery, and here we will have usually diminished tension. Sometimes the iritis runs a *chronic* course, being characterized by sluggishness of the pupil, cloudy aqueous, an occasional synechia, and by usually no marked painful symptoms. The conditions just mentioned mean that the eye has been the seat of disease for a considerable time, that in consequence the integrity of the lens (so-called *inflammatory cataract*), of the ciliary region—in fact, of the whole posterior segment of the eye—has been in a measure permanently impaired. The prognosis then is bad for anything like restoration of good vision.

The condition of the adjacent structures has an important bearing upon the prognosis.

Treatment.—In connection with the treatment of iritis the following rather striking sentences seem appropriate: "There is one ground, however, on which I strongly object to this ticketing of iritis with the names of various diseases—namely, that habit is likely to mislead the inexperienced practitioner into an endeavor to treat the name on the ticket, while the iritis may be neglected until it has done irreparable harm. I do not know of any disease which prevents the occurrence of iritis, and hence I do not know of any with which it may not sometimes be associated. . . . We do not understand a given case one whit better for calling it 'rheumatic,' and the term tends to relegate to the second place, as a mere accident of another affection, a malady in which all our skill will be necessary if we are adequately to discharge our responsibilities to the patient" (Robert Brudenell Carter).¹

Rest for the iris is reached by the instillation of atropin. This drug paralyzes the sphincter, stops the incessant movements of the pupil, reduces the hyperemia, and by dilating the pupil breaks loose the adhesions, which are not likely to recur during mydriasis. Atropin is to the eye in iritis very much what opium is to inflammations elsewhere in the body: it is, so to speak, the great anodyne in iritis. Generally, a solution of four grains to the ounce is strong enough to dilate the pupil if instilled every three or four hours; but if a solution of this strength does not produce the desired effect, a stronger one should be employed. Not infrequently success is attained only after using a solution of sixteen grains to the ounce. The surgeon should watch for the constitutional effects of the drug, but an iritis which calls for such a strong solution of atropin is apt to tolerate it without unfavorable results. No more than one drop is instilled at a time, and not oftener than every four hours. If constitutional effects appear, the strong solution should be abandoned at once; but ordinarily two or three instillations will give satisfactory evidence whether any good will follow its continued use. The employment of cocain along with atropin heightens the effect of the latter drug.

¹ *Ophthalmic Surgery*, by R. B. Carter and W. Adams Frost, pp. 180, 181.

The appearance of constitutional symptoms, however, no matter what be the strength of the atropin solution, necessitates a withdrawal of the drug, as well as of other mydriatics, such as scopolamin, duboisin, and hyoscyamin. When a full dilatation of the pupil is obtained, it may be no longer necessary to use the atropin so often; in other words, its use should be regulated by the condition of the pupil.

Hot applications, either moist or dry, are indicated. A small pad of surgical gauze steeped in the following lotion and applied to the eye as hot as can be borne rarely fails to give comfort: *Plumbi acetat.*, ʒj; *opii pulv.*, ʒss; *aq. bull.*, Oj. A roll of dry cotton and then a layer of oil silk should be placed over the pad. As soon as this application gets cool it should be renewed. Its good effects are especially evident when the inflammation is of a violent type. Poultices are valuable and are often employed. Cold applications are to be avoided, although some surgeons advise their use in traumatic iritis. Four or five leeches applied to the temples or the artificial leech (*Heurteloup*) are helpful in bringing about an abatement of the inflammatory symptoms, although this method of treating iritis has become less popular of late years. The Japanese stove or hot box is a most convenient method of applying dry heat. The box should be wrapped in a handkerchief or in any soft material and applied to the eye. A little bag filled with hops or bran and heated in an oven can be used in the same way. These various methods of applying heat are valuable, especially the first one.

According to Fuchs, Schweigger, and other writers, a hypodermic injection of muriate of pilocarpin ($\frac{1}{4}$ grain) every other day is very beneficial. Bromids and opiates are to be used when needed. So far as possible, the patient should be screened from direct rays of light. The administration of calomel in the earlier stages of the affection usually proves advantageous. Two grains are given in $\frac{1}{4}$ -grain doses. The good effects of this agent in all forms of iritis are most conspicuous. Not infrequently in cases in which atropin apparently has produced no mydriasis, after a thorough calomel action marked improvement in the condition of the pupil may be observed.

After the action of the calomel has been obtained treatment should be directed to the cause of the iritis. As a rule, the administration of salicylate of sodium in 20-grain doses, every three or four hours, will be found an admirable remedy in the painful stage of iritis. It matters not what be the origin of the disease, this remedy rarely fails to prove serviceable. After the painful stage has passed away this drug may be administered in smaller doses if there be a rheumatic or gouty diathesis present; if the iritis rests upon a syphilitic basis the surgeon should resort at once to biniodid of mercury and iodid of potassium, or inunction of blue ointment may prove the best method of getting the mercury into the system. A mercurial vapor-bath is also an excellent way of administering this remedy. Usually the mixed treatment is adopted in such cases, and, as has been said, this consists in the administration of the biniodid of mercury and iodid of potassium, which is continued not only till all the eye-symptoms have disappeared, but until one can be reasonably certain that the constitutional poison has been eliminated. Subconjunctival injections of bichlorid of mercury have been recommended by Darier and other surgeons; similar injections of physiological salt act equally well.

Iritis is uncommon in children, and is best treated by inunctions of mercury. In serous iritis the surgeon should be careful in the employment of atropin, as a glaucomatous condition often exists which the mydriatic would

tend to intensify. *Paracentesis* may be practised in these cases with advantage, and when increased intraocular tension persists iridectomy is indicated.

The majority of cases of iritis, properly treated, get well without adhesions; still, synechiæ may remain and may cause recurrent attacks. The operation of *corelysis*, which is not much practised now-a-days, was designed for the purpose of breaking loose these adhesions (see page 579). Whenever it is necessary to operate upon synechiæ no procedure is superior to *iridectomy* (see page 575). The presence of several broad synechiæ near one another might readily explain the occurrence of frequent attacks of iritis. Such synechiæ should be operated upon by an iridectomy at the point of attachment. One or two synechiæ are rarely responsible for a recurrence of iritis. Operative measures in connection with iritis are rarely demanded during the active inflammation, but rather in the sequelæ of the disease.

In those cases where the iritis has resulted from an injury, if there are any large pieces of iris protruding they should be abscised. A minute hernia, however, will probably do no harm and had best be let alone. The inflammation itself should be treated just as we would treat any plastic iritis. When the lens capsule has ruptured and the swollen masses of lens are pressing upon the iris the lens should be removed. In cases of *seclusion* or *occlusion of the pupil* iridectomy is indicated. Either of these conditions, if neglected, may end in total blindness. In seclusion, iridectomy is demanded because it relieves increased tension and re-establishes the communication between the anterior and posterior chambers, and by doing this the nutrition of the eye is at once improved and some vision may be obtained. For the same reasons iridectomy is demanded in occlusion of the pupil. But even in those cases where the intraocular tension is lowered and atrophy has set in, as is sometimes the case after total posterior synechiæ, the tendency of iridectomy is to do good by improving the condition of the eyeball. Such eyes may fill out again and regain some sight. Where the entire posterior surface of the iris is bound down to the lens capsule it is difficult to pull away the iris without more or less injuring the delicate ciliary region; hence iridectomy in such cases may be followed by irido-cyclitis, but inasmuch as such an eye will in all probability cause trouble in one way or another, iridectomy should be tried.

ANOMALIES OF THE ANTERIOR CHAMBER.

The depth of the anterior chamber varies within physiological limits. In infancy the anterior chamber is very shallow, becoming deeper as adult life is approached, while in old age it again becomes shallow. In myopia the anterior chamber is deeper than in hyperopia.

Pathologically, the anterior chamber shows variations in depth. It may be shallow from the pulling forward of the iris by anterior synechiæ or by the collection of masses of exudate behind the iris in total posterior synechiæ. Sometimes the periphery of the anterior chamber is deeper than the middle after a severe attack of cyclitis, and in these cases the outer zone of the iris is drawn backward by exudates. A shallow anterior chamber occurs in glaucoma, and also after the needling operation for cataract, when the lens swells up and presses against the iris, pushing it forward. A shallow anterior chamber is seen in the later stages of intraocular tumors.

Increased depth of the anterior chamber is seen in staphyloma of the cornea, in luxation of the lens into the vitreous body, in aphakia, and in hydrophthalmos.

The contents of the anterior chamber may be altered by the presence of blood (*hyphema*), pus, masses of lens-substance, foreign bodies, cysticerci, neoplasms, and cilia.

Blood in the anterior chamber as a general thing will disappear under a compress bandage, but if it persists and is evidently acting as a foreign body, paracentesis of the anterior chamber at its lower border should be performed. Hyphema most often follows injuries and contusions of, and operations upon, the eyeball. It is also seen after irido-cyclitis, with seclusion of the pupil and beginning phthisis bulbi, in which case the hemorrhage into the anterior chamber often repeats itself. Paracentesis under these circumstances does no good, the compress bandage being found more serviceable. Hyphema has been observed as a result of dysmenorrhea and purpura hæmorrhagica. Mooren and Weber describe patients who could bring on hemorrhage into the anterior chamber at will. Pus in the anterior chamber (*hypopyon*) is always a symptom, and must be treated according as it proceeds from the cornea or from the iris. It usually has its origin in affections of the cornea.

Foreign bodies, as particles of steel and glass, may pass through the cornea and rest in the anterior chamber and on the iris. An eyelash may find its way into the anterior chamber, and after a time give rise to an *implantation cyst* (see page 489).

Cysticerci are rarely seen in the anterior chamber. The parasite generally gives rise to symptoms of iritis, and can be seen sooner or later swimming around in the aqueous humor or it may be attached to some point of the iris. The *filaria sanguinis hominis* has also been observed in this locality. The parasites should be removed.

DISEASES OF THE CILIARY BODY.

Cyclitis.—Inflammation of the ciliary body does not exist as an isolated disease, but is usually an extension of an iritis or choroiditis. As a rule, iritis is present.

Etiology.—Inasmuch as the disease is secondary to either iritis or choroiditis, more often to the former, it has the same etiology. When it is not secondary to one of these affections it is the result of a wound or foreign body in the ciliary region, or it may occur in one eye as the result of a traumatic cyclitis in the other (sympathetic ophthalmitis).

Symptoms.—The disease is characterized by marked circumcorneal congestion and more or less hyperemia of the iris, which shows itself in dilatation of the blood-vessels and slight discoloration. The anterior chamber is deeper than normal at its periphery, owing to the traction of exudates from behind. These exudates are plastic in character—hence the name *plastic cyclitis*—and usually are not seen in the pupillary field. The pupil is often dilated. The hyperemia of the iris sooner or later passes over into iritis, and finally the choroid becomes involved. Sometimes these symptoms are much less pronounced; indeed, there may be entire absence of plastic exudates, and, while in the beginning the anterior chamber is deep, later on it becomes shallow. A condition may arise very similar to what is seen in serous iritis. Fine opacities make their appearance in the anterior part of the vitreous body—opacities which materially interfere with vision. The tension is decidedly elevated and the pupil dilated. Some authors speak of this somewhat milder aspect of the disease as *serous cyclitis*. Again, we may have the pericorneal

congestion and hyperemia of the iris intensified, and this hyperemia may extend to the retinal vessels, showing itself in tortuosity of the retinal veins. A characteristic symptom is *hypopyon*, which disappears and reappears again in a few days. This is the purulent type of the affection, and it is generally spoken of as *purulent cyclitis*. Just as in the plastic and serous types, the iris is always implicated.

Cyclitis is characterized by the general symptoms of inflammatory irritation—namely, ciliary neuralgia, photophobia, and lachrymation. The eyeball is exceedingly sensitive to the touch over the ciliary region. Vision is invariably impaired.

Pathological Anatomy.—Small-cell infiltration of the ciliary body is present, and this condition is especially marked in the purulent variety of cyclitis. Hemorrhages are frequent in all forms of cyclitis. Both the circular and radiating fibers of the ciliary muscle contain exudate, and this exudate (fibrinous) is considerable enough at times to push aside the individual fibers. The neighborhood of Schlemm's canal is always densely infiltrated, and no doubt the inflammatory products in this locality by blocking up the entrance into the canal have not a little to do with the development of glaucomatous tension. The formation of membranes is usually seen. The *cyclitic membranes* may cover the entire posterior and anterior surface of the iris, and also the ciliary body, and even extend into the vitreous body. This membrane not infrequently envelops the lens, and, contracting about it, cuts it off from its sources of nutrition. As a result of this the lens is often found as a small calcareous mass entangled in the meshes of the membrane and bearing no resemblance to its former shape. In the contraction which the cyclitic membrane undergoes the ciliary body is drawn away from its normal site, and is to be seen as a narrow strip of tissue, having lost its natural shape. This cyclitic membrane is composed of connective tissue with interlacing bands. All shapes of cells will be found present. In very light cases this membrane may disappear by resorption. Masses of black pigment are to be seen here and there throughout the diseased parts. According to Pollock, hemorrhages are common in the cyclitic membrane, although the author has not observed any in the specimens which have come under his observation. In the early stage the ciliary processes are thickened; finally, however, they undergo atrophy and become very much thinned. When the process has reached this stage atrophy of the eyeball is usually only a question of time.

Diagnosis.—The question is between iritis and irido-cyclitis. The symptoms which determine the existence of a cyclitis have been enumerated by Fuchs as follows: Inflammatory symptoms of considerable degree, especially if edema of the upper lid is present (this edema of the lid does not occur in pure iritis); sensitiveness to touch in the ciliary region; retraction of the periphery of the iris, indicating total posterior synechiæ; disturbance in vision more considerable than would be expected from the opacities within the confines of the anterior chamber; and, finally, tension either elevated or lowered.

Prognosis.—The prognosis in cyclitis is always grave, especially so in the *plastic form*. The cyclitic membrane usually covers the entire ciliary region, and in the contraction and organization which follow the retina and ciliary body are torn out of position, the lens undergoes degeneration, and atrophy ends the scene.

The *serous form* in its early stages is often characterized by a glaucomatous condition which is followed by softening and atrophy of the eyeball.

The *purulent form* of cyclitis, seen as a result of infection after cataract extraction, as a rule ends in sloughing of the whole eyeball.

Treatment.—The treatment is practically the same as that employed in iritis. Heat and atropin, then, should be used locally. The latter remedy is withdrawn when a glaucomatous condition is present. The constitutional treatment which has been suggested in connection with iritis is equally applicable here.

Injuries of the Ciliary Body.—Injuries of the ciliary body arise from penetrating and non-penetrating wounds of the ciliary body, and are fully described on pages 364 and 367.

Irido-choroiditis (*Chronic Serous Irido-choroiditis*).—This disease usually originates in the iris; that is to say, the presence of posterior synechiæ may result in chronic iritis which passes backward and invades the choroid. Sometimes the inflammation originates in the choroid and passes forward and involves the iris.

Etiology.—Old synechiæ are generally responsible for this affection. Where the disease starts in the choroid it not infrequently is to be attributed to a dislocated lens which has been either resting upon the retina and choroid or floating about in the vitreous body. Edward Meyer mentions instances where the affection was traceable to menstrual disturbances and to the climacteric.

The **pathological anatomy** is practically the same as that which has been described in connection with Iritis.

Symptoms.—Even when the process has originated in the iris the irritative symptoms are never conspicuous, certainly not to the extent in which they are found in iritis. The iris is often bulged forward, and may be pressing against the cornea. This condition, however, is only seen in those cases where the pupil is completely occluded and communication between the two chambers is interrupted. It is caused by the collection of effusions behind the iris. The vitreous body is generally filled with opacities. Pain, as might be expected, is an insignificant symptom. Visual disturbance is always present, and is in proportion to the condition of the pupil and involvement of the choroid.

Where the inflammation has started in the choroid the visual disturbances are more pronounced. Nearly always in this event there are detached retina, dense opacities in the vitreous body, and a degenerated lens. By the time the inflammation reaches the iris sight has been nearly extinguished. From now on the symptoms resemble those seen when the inflammation originates in the iris. Meyer has suggested the following points as important in deciding as to the probable origin of the affection, whether in the iris or choroid: In case the inflammation had started in the iris the patient would be apt to recall some attack of iritis, and it would be noticed that the structure of the iris had undergone changes to some extent, being discolored and atrophied. As a rule, the lens shows no participation in the affection till the process has found its way backward. When visual disturbances are absent one can be reasonably certain that neither the lens nor the vitreous body is to any extent involved.

If the process has started in the choroid, visual disturbances will always be prominent features, owing to the opacities in the vitreous body. Retinal detachment will be noticed, the intraocular tension will be lowered, and the lens will often be found to have undergone calcification. Neither of these forms exhibits acute symptoms, both being very insidious in character.

Prognosis.—Where the process has started in the iris and has been

properly treated in the early stages there is, comparatively speaking, hope for restoration of useful sight. But where the disease begins in the choroid the outlook is exceedingly bad. Even if the retina is not detached or the lens opaque, the integrity of the entire uveal tract has been to some extent permanently impaired.

Treatment.—Atropin must be employed, but it should be remembered that intraocular tension is sometimes elevated in the course of the disease. When the communication between the anterior and posterior chamber is interrupted, iridectomy should be performed, for a continuance of this condition means blindness. The surgeon should not hesitate to repeat this operation as often as the new pupil is closed with exudates, and should not be deterred even by a condition of diminished tension. The lens being diseased and more or less opaque, its removal is frequently indicated. Constitutional treatment should not be neglected. Mercury should be tried in the form of the bichlorid and in small doses. Iodid of potassium is also indicated.

SYMPATHETIC AFFECTIONS OF THE EYE.

Sympathetic Ophthalmitis.—This disease is one of the most interesting and at the same time the most obscure in the whole range of eye affections.

Definition.—Sympathetic ophthalmitis is an inflammation, usually plastic, but sometimes serous, which affects the iris, ciliary region, and choroid of one eye ("the *sympathizer*"), and which originates in a traumatic inflammation of the same parts in the other eye ("the *exciter*"). The three fundamental elements of true sympathetic ophthalmitis are—first, a traumatic irido-cyclitis of one eye; second, a plastic *uveitis* of the other eye; and third, a certain period of time which always elapses before the outbreak of the sympathetic disease—*i. e.* the period of incubation. The existence of these three factors certainly warrants the diagnosis of sympathetic ophthalmitis.

Etiology.—Penetrating wounds are chiefly concerned in the production of sympathetic ophthalmitis—wounds either from sharp instruments, such as scissiors and knives; or wounds caused by the entrance into the eyeball and the lodgement there of small fragments of steel, percussion caps, particles of stone or glass. Schirmer, Mackenzie, Knapp, and others report cases which followed simply a blow upon the eyeball without a rupture. This mechanism is entirely contrary to the rule, and most of these instances are open to grave criticism.

Penetrating wounds of the ciliary region are especially apt to give rise to the disease, and it makes no difference whether the wound is large or small. Mooren has described sympathetic ophthalmitis after the entrance into the eyeball of small particles of iron, and has seen it follow the bursting of the eye by a blow with a stick. According to Mackenzie, protrusion of the iris and its incarceration in the wound are conditions which are peculiarly liable to give rise to the disease.

Wounds which pass through the cornea and the pupillary border of the iris, even though the lens is injured and cataract results, are not as dangerous as when the wound passes through the ciliary border of the iris. Traumatic cataract of itself has no significance in the etiology of sympathetic ophthalmitis, though a swollen lens, by pressing upon the surrounding parts, can certainly aggravate an already existing cyclitis. The *operations* of iridodesis, discission, iridectomy, reclinacion, and cataract extraction have been followed by sympathetic ophthalmitis. Mackenzie states in his book that he never

saw sympathetic ophthalmia follow any of the operations for cataract. Among other causes mentioned by most writers are *intraocular tumors*, particularly the melano-sarcomata, and cysticercus is reported to have given rise to sympathetic ophthalmitis (two cases). There are good reasons, however, for regarding both sarcoma and cysticercus as very doubtful agents in the production of the affection, and the same may be said of *ossification* within the eye.

Symptoms.—Accommodative asthenopia is the first symptom, and shows itself on the slightest attempt to fix an object, no matter of what size or at what distance. This symptom may be lacking, and instead of it the patient sees a mist around everything. Pain is usually absent, but pressure on the ciliary region elicits tenderness which is often quite characteristic.

Pericorneal congestion is more or less marked. The media are cloudy. The earlier stages of the affection are associated with slight increase in intraocular tension, followed by vacillating conditions of tension, mounting up to a high grade in the glaucomatous stage, while at the last the tension is much diminished. The iris is hyperemic. Pagenstecher has called attention to the fact that in this kind of iritis the pupil can readily be dilated in spite of the synechiæ. It is possible for the process to disappear at this point and never return, but this is seldom the case. The attacks come at frequent intervals and with renewed intensity. After every recurrence the synechiæ are firmer and the pupil is harder to dilate. Pain may now develop. Small grayish dots appear on the posterior surface of the cornea. Synechiæ are to be seen extending all the way around the pupil. Recession of the iris periphery is present.

In nearly every case the primarily affected eye is blind before the outbreak of the sympathetic disease; but cases are on record where vision was still present in the injured eye at the time of the appearance of the sympathetic inflammation. The following constitutional symptoms may be seen: a quickened pulse, thirst, pallid complexion, and obstinate constipation. The course of the disease is usually tedious.

Sympathetic serous iritis is a much milder type of the disease. The symptoms are those of serous iritis. This may be regarded as a comparatively benign form of sympathetic ophthalmitis, which may pass over into the pernicious form—*plastic irido-cyclitis*—which has been described above.

Sympathetic papillo-retinitis has been observed a certain number of times, and, in contradistinction to the genuine sympathetic ophthalmitis, shows no tendency to relapses. Schirmer states that the disease has never been observed after the enucleation of the injured eye. It is a benign affection, and restoration of sight is the rule. A *sympathetic choroido-retinitis* has also been described.

Diagnosis.—The disease has no peculiar train of symptoms by which it can be invariably recognized. If pronounced objective symptoms of a plastic irido-cyclitis appear in an eye which had remained sound for three weeks after the fellow-eye had been the seat of a traumatic irido-cyclitis, the case may be regarded as one of sympathetic ophthalmitis. The diagnosis will be free of doubt if three weeks is considered as the earliest date for the outbreak of the sympathetic affection; later than the fourth month the diagnosis becomes more or less uncertain.

Mackenzie says that the disease may be complicated with scrofula and assume a good deal of the scrofulous character, or it may be complicated with syphilis. Cerebral complications have been mentioned in connection with sympathetic ophthalmia.

Sympathetic Irritation.—This condition was once regarded as simply

the forerunner of sympathetic inflammation ; but it is a much more frequent affection than the latter disease, and differs from it in several vital points. Photophobia, lachrymation, pains in the head and orbit, and blepharospasm are frequently present. The affection reminds one somewhat of phlyctenular conjunctivitis. The neuralgia is often remittent in character and very violent. There is concentric narrowing of the field of vision. Shadows and clouds are often seen when an effort is made to look at an object. More or less obscuration of objects occurs from time to time, the obscuration lasting several seconds, and then the objects appear as distinct as ever. The pupil is generally small, but the movements of the iris are intact. According to Noyes, the range of accommodation is diminished.

The disease shows itself at periods ranging from two and three weeks to fifteen and twenty years after the injury of the first eye, and is communicated to the sound eye through the medium of the ciliary nerves.

Pathogenesis of Sympathetic Ophthalmitis.—Up to 1858, Mackenzie's views prevailed pretty generally—namely, that the optic nerve was the channel of communication. Müller, however, concluded that the sympathetic disease was due to irritation of the ciliary nerves, together with an influence which affects nutrition, secretion, and accommodation. Müller's views gained many adherents, among others von Graefe ; indeed, the so-called *ciliary-nerve theory* became at once the popular one, and remained so for a long time.

The *optic-nerve theory* was revived by Horner and Knies in 1879.

In 1881, Snellen, Berlin, and Leber advanced the opinion that the disease was of parasitic origin.

Maats, under Donders' direction, in 1869 undertook the experimental solution of this problem, and his experiments were repeated at a later date by Snellen and Rosow. All three of these observers obtained negative results.

Of all the experimental work on this subject, that of Prof. R. Deutschmann of Hamburg has attracted the most widespread attention, and his results were regarded at first as absolutely conclusive. He claimed to have produced sympathetic ophthalmitis in the eye of a rabbit by injecting a drop of a suspension of the *staphylococcus aureus* into the vitreous body of the fellow-eye. Quite a number of experiments were made, and he felt justified in the following conclusions: That sympathetic ophthalmia is a parasitic disease which makes its way from one eye to the other by way of the optic nerves and chiasm. The organisms work their way forward by reason of a certain impetus which comes from their growth, as well as from their power of spontaneous movement. In this way they reach the base of the brain, where they are swept down by the lymph-stream into the sheaths of the opposite optic nerve, and thus reach the second eye. This movement on the part of the lymph-stream explains why the organisms do not spread themselves over the base of the brain and produce meningitis.

The experiments of Deutschmann were subjected to the closest scrutiny, and in spite of the work of Alt, Gifford, Mazza, Randolph, Limbourg and Levy, Schirmer, Greef, Ulrich, and Bach, there has never appeared any evidence to lead us to believe that Deutschmann's experiments are conclusive. In fact, the investigations of these observers strengthen the view which has been held, that sympathetic ophthalmitis cannot be produced in the lower animals, certainly not with the pus-organism. From this it would seem that Deutschmann's work is by no means conclusive, and that it is more than probable that this observer fell into errors of interpretation. The pus-organism probably plays no part in the production of the disease in man,

as is illustrated by the rarity of sympathetic ophthalmitis after panophthalmitis, where the pus-organisms are usually present in such great numbers.

Wounds of the ciliary region have been thought to peculiarly predispose to sympathetic ophthalmitis, but experiments on the lower animals have shown that so long as the instrument was sterilized the wound, no matter if located in the ciliary region, healed invariably with little or no inflammatory phenomena. Experiments of this character show that injuries in the ciliary region are not in themselves sufficient to give rise to sympathetic ophthalmitis, but that something else is necessary, a something modifying the character of the wound itself. A wound, however, which is infected would, for sound anatomical reasons, be more apt to set up sympathetic trouble if located in the ciliary region than if located anywhere else in the eye. Reference here may be made to the works of Bach and Schmidt-Rimpler, both of whom lean toward a somewhat *modified ciliary-nerve theory*.

The uniformly negative results of the various experimenters do not disprove the bacteric origin of sympathetic ophthalmitis, but before regarding the theory as proved the specific organism must be identified.

Prognosis.—The prognosis is always a matter of grave doubt. Well-established recoveries are rare. Waldispuhl, summing up the statistics of Prof. Schiess's clinic in Bâle, reports four recoveries in ten years. Cases of recovery are reported by Hirschberg, Laqueur, Schirmer, Rogman, and Randolph. Relapses are the rule, and this fact should lead us to be guarded in holding out the prospect of definite recovery. A patient who has passed two years without a relapse may be regarded as comparatively safe.

Treatment.—The *prophylactic* treatment naturally plays a most prominent part in dealing with sympathetic ophthalmitis, and it seems clear that the only certain prophylaxis is the enucleation of the injured eye. When sympathetic irritation exists and there is no special reason for believing that sympathetic inflammation will appear, resection of the optic nerve may be substituted for enucleation. This is often the case in eyes which have been lost from other causes than from penetrating wounds; for instance, in absolute glaucoma or where inflammation has destroyed the entire cornea and phthisis bulbi has followed. It would be safer to enucleate an eye blind from a penetrating wound. When the eye has some vision, it is an exceedingly difficult question to decide. The best guide in such a case is probably the tension and sensitiveness to touch. If the eyeball is sensitive to the touch and the tension diminished, and at the same time only light-perception is present, the chances of improvement for this eye are bad, and especially so if these conditions persist for several days after the injury. In this case enucleation is indicated.

When the injured eye is blind and sympathetic irritation is present in the other eye, it is best to enucleate.

When the injured eye possesses a little vision and symptoms of irritation appear in the other eye, every effort must be made to improve the condition of the injured eye; and this means to apply the rules governing the treatment of an irido-cyclitis.

When sympathetic inflammation has broken out the injured eye, if blind, should be removed; if not blind, the same course should be pursued as suggested when the condition is that of sympathetic irritation in the second eye—in other words, do not enucleate.

As regards medicinal agents, we possess nothing which exercises a specific influence for good in this disease. Atropin should be used, but always guardedly. Absolute rest and darkness are essential. Hot fomentations,

such as have been described in the treatment of iritis, do good service; so also the various ways of applying dry heat. Calomel in small doses is certainly helpful. Injections of pilocarpin have been known to do good. The injection of one drop of a sublimate solution (1 : 1000) has been strongly advocated by Abadie.

The influence of an operation is hurtful so long as there is present any evidence of an acute inflammation. The chief obstacle to vision is the opaque lens, and after all acute symptoms have disappeared Critchett suggests the following procedure: A fine needle is directed to the center of the opaque capsule, and the latter is pierced. Another needle is passed in from the opposite side, and by bringing the penetrating force of one needle to bear upon the other a small opening is made in the capsule. The points of the needles are then separated. In this way quite a rent is made. There is generally an escape of lens matter. Little or no reaction follows. An interval of several weeks is allowed to pass to permit the absorption of some lens substance, and then the operation is repeated, and so on, the operation being performed every time with two needles. Critchett and Story report cases where useful vision was obtained by this operation.

DISEASES OF THE CHOROID.

Congenital Anomalies of the Choroid.—Coloboma of the choroid is a circumscribed, frequently half-spherical-shaped defect in the choroid and retina, as seen in Fig. I., Plate 3. It presents a brilliant white color (due to the exposed sclera) with the ophthalmoscope, and it will be observed that the surface of the coloboma is distinctly below the plane of the retina; in other words, the surface is concave, and ridges and depressions can be seen upon it. Generally, two or three fine retinal vessels can be seen to dip at the edge of the coloboma, and then pass on over the surface of the latter. The coloboma usually begins a short distance from the optic nerve, or it may take in the papilla, and, assuming the shape described, pass downward and come to a stop at a certain distance from the ciliary body. It may reach a point so far forward that its anterior border can no longer be seen. The border of the coloboma is pigmented, and pigment-spots are often to be found upon its surface. Coloboma of the choroid is generally associated with the same defect in the iris. Such eyes are sometimes microphthalmic. The retina, as well as the choroid, may be absent at the site of the coloboma, and only the sclera remain beneath. At other times the retina may be present, and covers the coloboma in its entire extent. Of course there is always a defect in the visual field corresponding to the location of the coloboma. According to Meyer, myopia, amblyopia, and accommodative asthenopia are often present.

White depressions of various sizes situated in the macular region are regarded by some authors as similar defects, and are spoken of as *macular colobomata*, while Lindsay Johnson describes them as the atrophied remains of nevoid growths in the choroid.

Coloboma of the choroid is due to incomplete closure of the ocular fissure, and it is an affection which in a marked degree is transmissible by inheritance (see also page 192).

Albinism.—This is a condition where there is either a partial or complete absence of pigment in the choroid. The affection is congenital. The pupil has a reddish luster, and is somewhat smaller than normal. The iris appears reddish by transmitted light. This latter phenomenon is due to the

fact that much of the light is not absorbed, owing to the lack of pigment. The vessels of the retina and choroid may be plainly seen with the ophthalmoscope. Photophobia is the rule in this condition, and a shady place is always grateful to such patients. Nystagmus, amblyopia, and high degrees of myopia and astigmatism are usually coincident conditions. The cells which usually contain the pigment are present, but the pigment itself is absent. The affection is hereditary. The treatment consists in measures to ameliorate the photophobia and the correction of the refractive error.

There is a condition in which the stroma of the choroid is richly pigmented, while the epithelium is lacking in pigment, and consequently is transparent. Under these circumstances the so-called *choroidal intervacular spaces* exist, which look very dark, owing to the character of the stroma-pigment. This condition is sometimes seen in negroes.

Hyperemia of the Choroid.—This condition undoubtedly exists, but is questionable whether it can be diagnosticated. According to de Schweinitz, we may assume hyperemia of the choroid when the nerve-head presents distinct redness, which is imperfectly differentiated from the unduly flannel-red appearance of the surrounding choroid, or when the choroid, instead of exhibiting its usual red color, has changed into what has been denominated a "woolly choroid," with faint dark areas in the periphery, indicating the interspaces between the choroidal vessels and more or less retinal striations surrounding the disk. The condition is ordinarily supposed to be due to "eye-strain," and should be treated accordingly. Dark glasses and complete rest should be ordered until the changes described have entirely disappeared, and then the error of refraction should be corrected.

Choroiditis.—Inflammation of the choroid may be either *non-suppurative* (commonly called *exudative*) or *suppurative*.

1. **Exudative Choroiditis.**—*Etiology.*—The most common cause is syphilis, both hereditary and acquired. Any profound disturbance in the nutrition, such as scrofula or anemia, may give rise to the same disease. Meyer mentions the fact that this form of the disease is sometimes found in women who suffer with menstrual disturbances or at the climacteric. Myopia cannot be said to cause choroiditis in the same sense as syphilis, for the changes in the former are more of the nature of degenerative changes than of true inflammatory ones, and are due to the stretching to which the posterior segment of the eyeball is exposed in myopia of very high grade.

Pathological Anatomy.—The histological changes are usually sharply defined, and correspond to the ophthalmoscopic picture; that is to say, there is no general involvement of the choroid except in cases of many years' standing. The vessels are frequently engorged, and round-cell infiltration is found near them. Small open spaces containing fibrin and hyalin drops are often seen. Hemorrhages are occasionally observed. The pigment-cells are sometimes devoid of processes, and often have a proliferation of pigment. Later on the choroid becomes atrophied and fibrous, and the pigment-clumps become scarcer and may disappear entirely. In those cases where the exudate has forced its way into the layer of rods and cones, this layer may be completely broken up.

The following interesting changes are mentioned by Schweigger as occurring in *disseminated choroiditis*: Little nodules are seen scattered through the stroma of the choroid, which consist of nucleated fibers and non-pigmented cells. The surface of these nodules is at first covered with very black pigment-epithelium, which gradually disappears from the center outward, so that we have the well-known picture of a white area surrounded

PLATE 3.

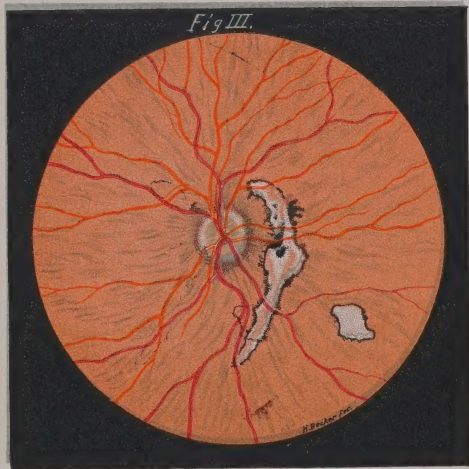
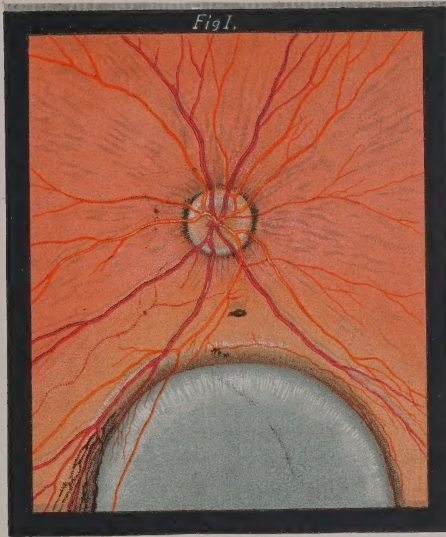


FIG. I.—Coloboma of the choroid ; the case also had a coloboma of the lens.
FIG. II.—Disseminated choroiditis ; nearly normal, central acuity of vision.
FIG. III.—Rupture of the choroid from a blow with a ball.

with a black ring. At points we have a proliferation of the pigment-epithelium. The new-formed cells contain no pigment. When the process extends into the retina, we have an elongation of the radiating fibers, and they sometimes bend abruptly and are found bound fast to the choroid.

Symptoms.—With the ophthalmoscope will be seen yellowish-white spots scattered over the red fundus and lying under the blood-vessels of the retina (*recent choroiditis*). As time goes on this yellowish color disappears, and gives way to white, which is an indication that the choroid has lost its pigment (*atrophy*) and that the sclera is exposed. Specks of pigment are often to be seen on these atrophic areas. Sometimes the exudates are very small, and are found either isolated or in groups, and located in various parts of the fundus (*disseminated choroiditis*). Dust-like opacities and floating membranes in the vitreous body are common in exudative choroiditis (Fig. II., Plate 3).

Disturbances in vision are always present, showing themselves in narrowing of the field and loss of visual acuity, though it is astonishing how good vision may be in cases where the ophthalmoscope shows an involvement of apparently the entire fundus. The patient complains of seeing specks floating before the eyes. Photophobia, metamorphopsia, and night-blindness are present in a certain number of cases. The disturbances in vision arise partly from the opacities in the vitreous body, and partly from a functional disturbance of the retina, which is always to some extent involved.

In the earlier stages of disseminated choroiditis there is often a coincident dilatation of the retinal blood-vessels, owing to the involvement of the retina. This variety of choroiditis is sometimes called *syphilitic choroiditis* (see page 419).

Again, in the vicinity of the optic nerve rather prominent foci of inflammation, composed of transparent, non-pigmented tissue, may be found; and at these points the retina is atrophic. These areas appear at first as deeply pigmented spots, having a bright yellowish center and surrounded by a red

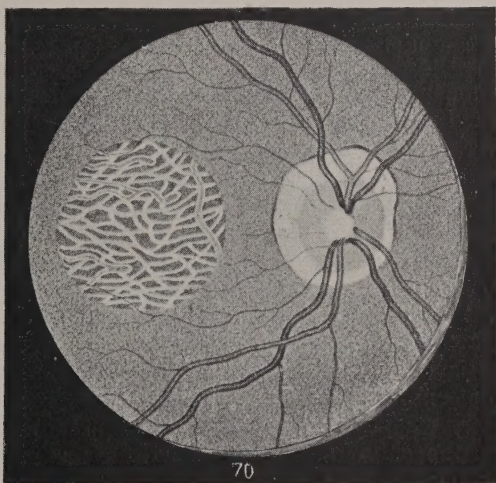


Fig. 229.—Central choroiditis (De Wecker and Jaeger). The circular character of the patch and the exposure and partial atrophy of the deep vessels are well shown.

hyperemic ring. Later on these areas become flatter, are bordered with pigment, and traversed by choroidal vessels. This is *areolar choroiditis* (Förster). In both areolar and disseminated choroiditis the regions of the fundus between the diseased areas are usually sound in the earlier stages of the affection.

Sometimes the exudates are located chiefly in the macular region (*central choroiditis*, Fig. 229). The disturbance in visual acuity in this variety of the affection is very pronounced. While any of the causes mentioned above may give rise to central choroiditis, its most frequent cause is myopia of high grade. Among other special causes are contusions of the eyeball; for instance, a blow which gives rise to rupture of the choroid will often be followed by choroidal changes in the macular region.

The macular region may be the seat of a large white patch, while the rest of the fundus is normal (*senile areolar atrophy of the choroid*).

Again, in the same locality may be found small white, glistening spots closely resembling the changes which are seen in albuminuric retinitis. Generally these changes are found in both eyes. They constitute the *senile guttate choroiditis* of Tay and Hutchinson. The white specks are due to colloid degeneration of the choroid (Fig. 230).

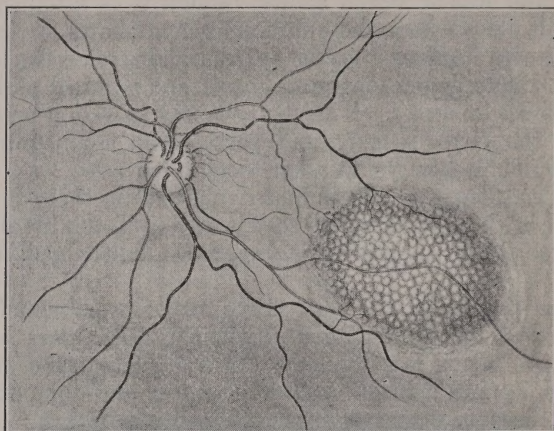


FIG. 230.—Colloid change in the macular region (de Schweinitz).

Changes in the macular region, consisting of white plaques of various sizes and shapes, associated with atrophy of the choroid at the border of the disk, are often seen in high grades of myopia, and are spoken of as *myopic choroiditis*. The peculiar crescent-shaped area at the disk is known as *posterior staphyloma*, and is to be attributed to the protrusion of the sclera backward.

Patches of choroidal atrophy may be found at any point in the fundus, and may result from various causes, as from the action of brilliant light or the glare of heat, or from the so-called *hemorrhagic choroiditis* in young men (Hutchinson). These and other changes in the choroid which are typical of no special lesion are regarded as *unclassified forms of choroiditis*.

Diagnosis.—It is certain that in the majority of cases there are changes in the retina, so this condition may be assumed to be present. It is very often a question, however, whether the exudates seen with the ophthalmoscope lie in the retina or the choroid. Retinal exudates are supposed to be more opaque, and to be bordered by fine radiating lines corresponding to the direction of the nerve-fibers (Meyer). The blood-vessels of the retina in retinitis are tortuous, and often disappear under the exudates, while the course of the retinal vessels may be plainly traced when the exudates lie in the choroid; and this rule also applies to the situation of pigment-masses. Masses of pigment resembling bone-corpuscles are always situated in the retina (Nettleship).

Prognosis.—When atrophy of the choroid has taken place, the outlook is absolutely bad. Floating opacities in the vitreous body, as a rule, persist in spite of all treatment. As a general thing, the prognosis in choroiditis is unfavorable, and worse when the changes are prominent in the macular region. Of course the earlier the disease is recognized the more may be hoped for from treatment. Those cases clearly due to syphilis offer the best chances for improvement.

Treatment.—Antisymphilitic treatment in certain cases is followed by improvement, and even by cure. Recurrences are very common. In cases where syphilis can be excluded the mercurials and iodid of potassium through their absorptive power do good service, and should be used. The application of six or eight leeches or the artificial leech (Heurteloup) to the skin behind the mastoid process has been strongly recommended. Good results have been reported from the injection of $\frac{1}{4}$ grain of muriate pilocarpin every other night. Cod-liver oil and iron are specially indicated in children. The eyes should not be used for work, and dark glasses are advisable. Subconjunctival injections of bichlorid and cyanid of mercury have been recommended by Darier and others, but are of doubtful value.

2. Suppurative Choroiditis.—As the name implies, this is an affection of the choroid suppurative in character, and one which rapidly involves the iris and ciliary body.

Etiology.—The most frequent causes are injuries from penetrating foreign bodies. Suppurative choroiditis sometimes follows unsuccessful cataract operations. No matter what kind of instrument produces the wound, after all infection is responsible for the suppurative process. Sloughing ulcers of the cornea and the progress inward of the suppuration may be responsible for the affection.

The disease may result from *endogenous infection*—that is to say, from the organism itself. In these cases septic substances form a focus of inflammation, get into the circulation, and are carried into the choroidal vessels, and here stop and form a septic embolus, which at once gives rise to the choroiditis (*metastatic choroiditis*). This phenomenon is sometimes seen in the pyemia of the puerperal state. Suppurative choroiditis may follow cerebrospinal meningitis and typhus. Inflammation of the umbilical vein and thrombosis of the orbital veins have been known to cause the disease.

Pathological Anatomy.—The choroid and retina are enormously thickened and infiltrated with round-cells. In fact, in advanced stages the choroid and retina lose their identity almost entirely, and we simply find large areas made up of coagulated material and round-cells, with here and there a clump of pigment-granules. The exudate having found its way into the vitreous body, the latter is converted into a homogeneous mass of exudate. Round-cell infiltration of the iris and ciliary body is seen with numerous hemorrhages and more or less change in the pigment-epithelium, the latter changes manifesting themselves either in a breaking up or in an entire disappearance of the epithelium.

Symptoms.—The lids are red and swollen, so much so that often they cannot be opened, and the orbital tissue is frequently so infiltrated as to interfere with the movements of the eyeball. The conjunctiva is intensely congested, often reaching the grade of chemosis. The cornea sooner or later becomes clouded, but before the media have lost their transparency one can see the characteristic yellowish reflex in the pupil, arising partly from the mass of exudate in the vitreous body and partly from the detached retina. Hypopyon and anterior synechiæ are usually present. The intraocular tension is elevated in

the earlier stages, the pupil is dilated, and the anterior chamber shallow. Intense throbbing pain is felt in the orbit and brow, and sight is lost. Chills and fever are frequently present.

Diagnosis.—Only one condition simulates the peculiar reflex seen in suppurative choroiditis, and that is glioma of the retina. Apart from the general history, there is this marked difference. In suppurative choroiditis the tension is always elevated in the stage when it is apt to be first seen, and this condition is followed soon by either lowered tension or by bursting of the eyeball. In glioma the tension in its early stages is normal, and increased tension does not make its appearance till the latter stages of the affection. The previous history of the case is probably the most reliable basis for a differential diagnosis (see also pages 400 and 494).

Prognosis.—The outlook is absolutely bad. Loss of sight and shrinkage of the eyeball (*phthisis bulbi*) are the rule.

Treatment.—It is not possible to put a stop to the process, so all that can be done is to relieve the suffering of the patient—locally by hot applications, and internally by the administration of narcotics. Violent and persistent pain can be remedied by a free incision in the sclera. This may be found necessary in those cases of *panophthalmitis* where spontaneous rupture is slow in taking place.

As to the advisability of enucleation or evisceration in the acute stages of panophthalmitis, there is a difference of opinion. While a few cases of death have been reported after the enucleation, the risk is very slight, and it is by no means certain that the operation was responsible for the unhappy issue in those few cases. Meningitis has been reported after evisceration, and, indeed, where no operation was performed.

Tuberculosis of the Choroid.—This condition was first described by Jäger, and later by Manz, Busch, and Bouchut. The tubercles appear as small, round, slightly elevated, reddish or gray nodules, varying in size from 0.3 to 2.5 mm. The spots are sometimes quite numerous, even as many as fifty being noticed, and they are distinguished from somewhat similar choroidal changes in that they are not surrounded with a border of pigment. These nodules are usually found in the vicinity of the optic nerve.

The little nodules on anatomical examination are seen to possess the typical structure of tubercles. A part of them sometimes undergoes caseous degeneration (Manz). Giant-cells have been observed in them (Alt), and the *tubercle bacillus* has been demonstrated. According to Cohnheim, the affection forms one of the symptoms of acute general miliary tuberculosis, and it may aid in diagnosing the constitutional disease.

Sometimes a *solitary tubercle* is observed, which grows like any other intraocular neoplasm, and finally breaks through the sclera. This condition is a rare one, and is usually associated with cerebral tuberculosis, and is an affection peculiar to children.

Treatment.—Miliary tubercles demand no special treatment, but enucleation is the proper course to pursue in solitary tubercle in order to prevent a general infection.

Atrophy of the Eyeball.—Atrophy of the eyeball consists in a gradual diminution in the size of the eyeball, accompanied with diminished intraocular tension and altered shape. The change in the size and shape is to be attributed to the contraction of the exudates within the eyeball—exudates which have resulted from the plastic irido-cyclitis. Fuchs says that this condition differs from *phthisis bulbi* in that the latter affection is a much more rapid one, and results from the rupture of the eyeball and the evacuation of

its contents. After panophthalmitis the eyeball often becomes as small as a hazelnut or even smaller, while in atrophy no such stage is commonly reached.

Essential Phthisis Bulbi (*Ophthalmomalacia*).—This is a very rare affection in which there are lowered intraocular tension and diminution in the size of the eyeball without any assignable cause. Photophobia, neuralgic pains, myosis, and partial ptosis are sometimes present. The condition may last for several days, and then disappear without leaving any traces. It is supposed to be due to a lesion of the sympathetic. It may follow injury.

Rupture of the Choroid.—Rupture of the choroid is caused by a powerful blow upon the eyeball. The blow has the effect of stretching the sclera. At first it is impossible to make out the exact nature of the trouble, owing to the extravasations in the vitreous body. As soon as the vitreous body becomes transparent one can see a long, bright, sickle-shaped streak on the temporal side of the papilla, and with the concavity of the sickle directed toward the papilla. When first seen the streak is yellowish in color, but it soon becomes white and has a pigmented border. Small spots of choroidal atrophy are frequently seen in the neighborhood of the rent, and these changes may invade the macular region. It is certain that the retina and sclera are both injured. The retinal vessels will generally be seen passing over the injured point, except in those cases where the retina itself participates in the rupture. No good reason has been advanced as to why the posterior part of the choroid is disposed to rupture. We may have the rupture occurring in one spot or in several spots (Plate 3, Fig. III.).

The vision at first is almost extinguished, but after the blood in the vitreous clears away good vision is often restored. Cases are reported by Knapp and Saemisch where central visual acuity returned to almost the normal standard. As a consequence of rupture of the choroid, retinal detachment, glaucoma, and optic-nerve atrophy have been observed. Traumatic cataract and dislocation of the lens are also complications (see page 364). The treatment consists in a compress bandage and atropin. It is doubtful whether the subsequent use of strychnin or iodid of potassium does good.

Detachment of the Choroid.—This is an exceedingly rare condition. One observes a round-looking mass projecting into the vitreous body. The surface of this mass is perfectly smooth, and the retinal vessels can be seen upon it. The color of the protuberance is sometimes yellowish, with pigmented areas here and there about it. Meyer says it may be distinguished from detachment of the retina because it does not move with every movement of the eyeball. Detachment of the retina is usually present. The tension in detachment of the choroid is always diminished. Marshall thinks that the following factors are necessary to cause this condition: hyalitis with shrinking; choroido-retinitis leading to adhesions and serous exudation between the choroid and sclerotic.¹ Risley reports detachment of the choroid caused by the concussion after the discharge of a gun.²

Ossification of the Choroid.—This is not infrequently found in shrunken eyes where sight has been lost many years previously. A thin shell of bone is found in the posterior part of the eyeball, with a small hole in its middle for the passage of the optic nerve; or sometimes simply a spicule is found. The mass possesses all the histological characteristics of bone anywhere else in the body. The eyeball is often painful to the touch, and it may give rise to sympathetic irritation; so enucleation is always advisable. *Calcareous degeneration* is also common in eyes of this character.

¹ "Detachment of the Choroid," by C. D. Marshall, *Trans. Ophthal. Soc. U. K.*, xvi. p. 98.

² *Amer. Journ. Ophthal.*, March, 1897.

INJURIES OF THE EYE AND ITS APPENDAGES.

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THE eye may be injured in a great variety of degrees and ways by contact with overheated substances, as hot vapors, liquids, or solids; or with caustics or escharotics, as acids, caustic alkalies, and lime, whereby the parts become burned or corroded; or by mechanical forces or bodies impinging upon it, whereby its tissues are contused, lacerated, abraded, cut, or penetrated.

Injuries of the Cornea and Conjunctiva from Heat and Chemicals.—Heat and chemical substances affect the tissues of the eye similarly. The anterior portion of the eyeball is most exposed to these agencies, and is therefore more frequently injured by them, the palpebral conjunctiva suffering only when the injurious substance gets beneath the lids. Burning gases and hot water or oil cool quickly, and seldom reach the surface under the lids. Their effects, therefore, are more superficial and less extended than those of hot or molten metals or of chemicals and lime.

When the injury is superficial a whitish film is formed which is soon thrown off, and the parts rapidly regain their epithelium and their normal transparency (Plate 4, Fig. I.). When the injury affects the deeper tissues the eschar is thicker, and its elimination leaves a granulating surface, which on healing may contract or lead to adhesions if it is on the conjunctiva, or produce an opacity if it is on the cornea. Should the whole thickness of the cornea be involved, a perforation will take place with all of its consequences.

Symptoms.—Besides the appearances above noted, there are, immediately after the injury, severe burning pain, redness of the eyeball, and lachrymation. Later, active inflammation may take place, with increased redness, and even chemosis, of the conjunctiva and swelling of the lids. When a considerable surface of the conjunctiva is affected, the secretion becomes muco-purulent, and sometimes purulent. Implication of the cornea causes much pain and impairment of vision.

Treatment.—When the case is seen immediately and the injury is from an acid, it should be neutralized by the application to the affected area of a weak alkaline solution. For this purpose bicarbonate of soda or bicarbonate of potash (saleratus) may be used. The latter has the advantage of accessibility, as it may be found in almost every house. When the offending agent is lime, caustic soda, caustic potash, or other alkali, it may be neutralized by an acid largely diluted, and here vinegar, diluted, answers the purpose, and generally is also within easy reach.

After neutralizing the chemical and removing such foreign substances as may be present, the parts should be cleansed with some mild antiseptic, and

PLATE 4.

FIG. I.

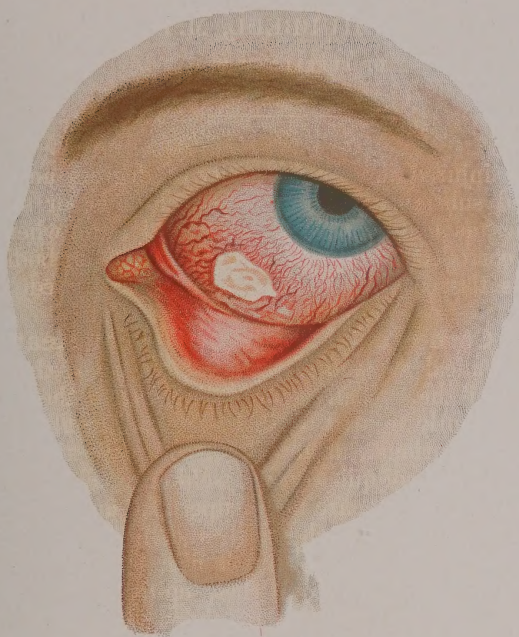


FIG. II



FIG. I.—Burn of the bulbar conjunctiva from bichlorid of mercury.

FIG. II.—Rupture of the sclerotic, with hemorrhage into the anterior chamber (after Sichel).

iced cloths kept constantly applied over the eye till the burning pain has ceased. Frequent instillations of a cocain solution will contribute much toward the relief of the pain. The subsequent treatment is the same as that of conjunctivitis or of ulceration of the cornea from other causes.

In cases where opposing surfaces of the conjunctiva are denuded, but the retrotarsal fold is unaffected, adhesion, or *symblepharon* (Fig. 231), may be prevented by frequently drawing the lid away from the eyeball or by interposing some smooth, flat substance between the lid and ball. But when the denudation includes the retrotarsal fold, such efforts will be absolutely fruitless and may as well be withheld. Should the lesion of the ocular conjunctiva be limited in extent, it may be covered, either immediately after the injury or after the eschar has sloughed off, by drawing the surrounding conjunctiva over it with sutures introduced from side to side. Sometimes adhesions can thus be very much restricted or even prevented.

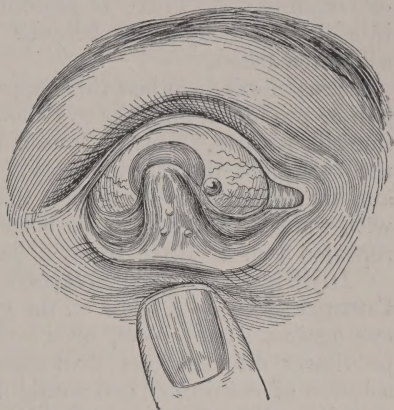


FIG. 231.—Symblepharon (Sichel).

Mechanical Injuries of the Cornea without the Lodgement of Foreign Bodies.—These injuries include *scratches, contusions, superficial punctures, and erosions*, and may be inflicted in a multitude of ways.

Symptoms.—Injury of the cornea is determined by inspection, aided by oblique illumination, and is shown by loss of epithelium and irregularity of the injured surface. The denuded area may be detected by coloring it with fluorescein (page 145). Should ulceration or suppuration of the cornea take place, there will be added the appearances which these conditions usually present.

There is a scratching, pricking feeling in the eye at first, and afterward there may be severe pain. The eyeball becomes red, there is free lachrymation, and, with a lesion centrally situated on the cornea, vision is more or less impaired.

Prognosis.—This depends on the part injured and the progress of the case. There is impairment of sight in proportion to the involvement of the center of the cornea and the distortion of it which the injury and cicatrization cause. Wounds of the cornea are extremely liable to infection, and are therefore prone to ulceration or suppuration.

Treatment.—The eye should first be cocainized, and the injured parts gently but thoroughly cleansed with 1:4000 solution of bichlorid of mercury, care being exercised not to rub away or loosen the adjacent corneal epithelium. Atropin solution should then be instilled and a compress bandage applied.

The subsequent treatment consists in using some form of antiseptis, continuing the instillations of atropin, and keeping the eye covered. Should ulceration or suppuration take place, it is to be treated as elsewhere described (see page 315).

Mechanical Injuries of the Conjunctiva without the Lodgement of Foreign Bodies.—The conjunctiva may be *cut, lacerated, punctured, or contused* in many ways and by many kinds of objects.

Symptoms.—An effusion of blood (*ecchymosis of the conjunctiva*), sometimes only slight, underneath the conjunctiva at the site of the injury is one of the most constant symptoms. The ecchymosis usually spreads, and may even surround the cornea. A puncture or small cut is not always apparent, but when the wound is larger it is recognized by its roughened surface and reddened edges, and later by the whitish appearance of the parts denuded of conjunctiva. There is seldom any pain beyond a scratching feeling, as if a foreign body were beneath the lid, and the inflammatory reaction is seldom marked.

Treatment.—When the conjunctiva is cut or torn in such a manner as to gap or produce a flap, the eye should be cocaineized and the wound closed by fine silk sutures. Instillations of boric-acid solution afterward are usually all the treatment that is necessary. Should the ecchymosis, however, be large and disfiguring, its absorption may be hastened by bathing the closed eye with water as hot as can be borne for fifteen or twenty minutes at a sitting, repeated two or three times a day.

Injuries of the Eyeball from Contusion, Concussion, and Compression.—A blow on the eye by some blunt substance, or striking the eye against some object, or a sudden compression of the eyeball by some peculiarly directed force, or a violent explosion near the eye, may result in a solution of continuity and contiguity of its tissues, without their being penetrated by the offending agent itself. Such lesions are *single* or *multiple*, and consist in general contusions of the ball; rupture of the intraocular blood-vessels; rupture of the outer coat of the eye; laceration of the iris; displacement of the iris; laceration of the ciliary body; detachment of the choroid; rupture of the choroid; detachment of the retina; rupture of the zonula; dislocation of the lens; rupture of the capsule of the lens; iridoplegia; cycloplegia; spasm of the circular fibers of the iris; spasm of the ciliary muscle; anesthesia of the retina; "commotion" of the retina; and pigmentation of the retina.

Contusion of the Eyeball.—A blow on the eye may bruise the tissues without causing any apparent laceration or other lesion.

Symptoms.—There are redness and tenderness of the eyeball, and sometimes pain. Occasionally there is produced anesthesia of the retina, mydriasis, loss of accommodation, spasm of the sphincter of the iris, or spasm of the ciliary muscle, with the symptoms belonging to each.

Traumatic amblyopia or *amaurosis* (Berlin) is said to exist when the vision becomes slightly and transiently impaired or entirely and permanently lost without visible anatomical change in the retina.

A similar condition has been described as *traumatic anesthesia of the retina* (Leber). This is shown by weakness, unsteadiness, and impairment of vision, with restriction of the visual field—conditions which may continue for several weeks or months (see also page 414).

In *mydriasis* (*iridoplegia*) the pupil is usually widely dilated. The dilatation may disappear in a few days, but it is frequently permanent. While it exists vision is dazzled when exposed to ordinary daylight from the admission of too much light into the eye.

Paralysis of the ciliary muscle (*cycloplegia*) is often associated with mydriasis, although it may exist alone. The patient cannot accommodate for near objects, while the vision for distance may not be affected.

Spasm of the iris and ciliary muscle is indicated by a contracted pupil and by apparent myopia.

Treatment.—The eye should be given rest, cold applications should be

used, pilocarpin or eserine should be instilled for mydriasis and loss of accommodation, and atropin for spasm. Retinal anesthesia has been treated by "suggestion," on the theory that it is hysterical in its nature.

Rupture of the Eyeball.—Rupture of the outer coat of the eye is of rare occurrence, and is produced by extreme violence. Its location is scarcely ever in the cornea, but it is most frequent in the anterior part of the sclera. It is largely determined by the position of the eye at the time of the injury, which is usually upward; the direction of the blow, which is generally from below or from below and outward; and the comparative weakness of the sclera between the margin of the cornea and the ciliary region. It is found, therefore, in most cases from one to three millimeters behind the margin of the cornea in the upper or upper and inner part of the sclera. Sometimes it is in the upper and outer part, or directly inward or directly outward. It is seldom directly outward. The rupture usually spans one-third to one-half of the periphery of the cornea. Partial rupture may occur in which the inner fibers of the sclera are torn, while the outer ones are more or less stretched. Rupture of the eyeball occurs almost exclusively in adults (see Plate 4, Fig. II.).

Symptoms.—A rupture of the eyeball is signaled by the following symptoms: immediate loss of sight, which may or may not be regained afterward; softness of the eyeball; congestion and ecchymosis of the conjunctiva; and, when the conjunctiva is not torn or the rupture is not situated anterior to its circumcorneal attachment, the presence of a distinct elevation or "tumor" of the conjunctiva from the extrusion of more or less of the intraocular structures. The edges of the rupture are ragged, and the lens, iris, ciliary body, choroid, retina, or vitreous humor may be protruding through it or entangled in it. Sometimes the iris or lens is entirely expelled from the eye or lodged underneath the conjunctiva. The other appearances are such as belong to rupture of blood-vessels, laceration of the iris, rupture of the choroid, and other lesions.

There is usually very little if any pain at any time, unless, as sometimes happens, severe inflammation supervenes.

Prognosis.—The prognosis is usually very unfavorable, although in exceptional cases useful vision has been known to return. The extensive lesions, the large amount of hemorrhage, the excessive loss of vitreous, and the inflammatory reaction are generally sufficient to produce loss of vision and shrinking of the eyeball. Should the wound unite imperfectly, *scleral staphyloma* may follow. Incarceration of the iris or ciliary body in the wound or a laceration extending into the ciliary body may cause *sympathetic ophthalmitis*.

Treatment.—When, because of very great injury of the intraocular structures, excessive hemorrhage into the vitreous chamber, or extreme collapse of the eyeball, there is no possible hope of recovery, time and suffering can be saved by enucleating or eviscerating the eye at once. But when there is reason to believe that there is a possibility of the eye being saved with partial vision, the practitioner is justified in making an attempt to do so, at least for two or three weeks, during which time there is scarcely any danger of sympathetic inflammation. At the end of this time, if the symptoms promise well, the effort may be continued. But if not, further risk should not be taken, except under peculiar and pressing circumstances.

If it be decided to try to save the eye, it should be cocaineized, and with strict antiseptic precautions the rupture should be closed. To this end the conjunctiva, if not already ruptured, should be opened (contrary to the old

practice), and all extraneous substances carefully removed, both from the outside and from between the lips of the wound. Protruding iris, ciliary body, or other tissue should be withdrawn and excised or cautiously replaced, as incarceration would interfere with solid union or cause irritation in the future. Any loose shreds hanging from the edges of the wound should also be cut off. Having thus made the wound as clean and smooth as possible, a sufficient number of fine antiseptic sutures, either silk or catgut, should be introduced from within outward and at a depth sufficient to hold firmly, and its edges closely drawn together. After tying and cutting off the threads, the wound should be covered, if possible, by conjunctival flaps held in place by suitably adjusted sutures. Catgut sutures may be allowed to remain, but silk ones should be removed in two to four days.

Having closed the wound, a solution of atropin should be instilled, the eye bandaged, and the patient put to bed and kept quiet for several days. Cold applications are useful, especially if inflammatory reaction threatens. Other conditions and symptoms are to be treated as they arise and according to directions given elsewhere.

When a case is not seen until after the wound has united the practitioner is generally quite powerless. Prolapse of the iris may be reduced by the galvano-cautery. Other lesions must be treated according to indications.

A *rupture of the cornea* is to be treated similarly to that of the sclera, except that it is not usually practicable to introduce sutures or to cover the wound with conjunctival flaps (see also page 569).

Rupture of Ocular Blood-vessels.—Contusion of the eyeball may rupture blood-vessels of the iris, causing effusion of blood into the anterior chamber—*hyphema*—or of the choroid or retina, causing effusion of blood into or beneath these membranes or into the vitreous humor—*hemophthalmia*.

Symptoms.—There is seldom any pain beyond that produced by the contusion. The presence of the blood usually obstructs the vision, either partially or totally. When the blood is in the anterior chamber it settles to the dependent portion, and its upper edge or surface is straight (see Plate 4, Fig. II.). It is seen in its natural color or perhaps a little darkened. Blood in the vitreous humor appears with the ophthalmoscope as a dark object, and when large in quantity it may be seen, with the pupil dilated, by oblique illumination as a dark-red reflection.

Prognosis.—A hemorrhage into the anterior chamber of a previously healthy eye is absorbed in two to four days, but one into the vitreous humor requires weeks or months for absorption, and when it is of considerable size it often leaves permanent residues and opacities, and may even lead to disorganization of the vitreous humor and shrinking of the eyeball.

Treatment.—The treatment is limited to covering the eye, giving it rest, and instilling a weak solution of atropin. In some cases it may be preferable to instil pilocarpin instead of atropin. Hot water or hot fomentations continuously applied over the eye for fifteen to twenty minutes two or three times a day hasten the absorption of the blood. The internal administration of iodid of sodium or similar alterative is useful.

Contusion-injuries of the Iris; Lacerations or Ruptures of the Iris.—Aside from hemorrhages, the most common lesions of the iris from blows or contusions are rents or lacerations. In extreme cases the iris may be torn entirely from its peripheral attachment (*traumatic aniridia*), and when the eyeball is ruptured it may be expelled from the eye or a segment of it may be torn away instead of the whole (*traumatic coloboma*). Partial detachment of the iris from its periphery at one or more points (*iridodialysis*)

is the form of rent most frequently found. *Radial lacerations* rarely occur, and are usually at the pupillary border (*rupture of sphincter*).

Symptoms.—Hemorrhage is usually present in the anterior chamber at first, and it may obscure the parts. But after its absorption inspection with or without oblique illumination will reveal a laceration or rent of the iris if one exists, or the absence of the iris if it has been expelled. When it has been entirely detached, but not expelled, it will be seen in the bottom of the anterior chamber as a rounded mass, dark in color at first, but soon changing to an ash-gray. It rapidly shrinks to an inconspicuous size.

In a rent of the pupillary border, involving as it does the sphincter of the iris, the pupil is widely and permanently dilated (Fig. 232).

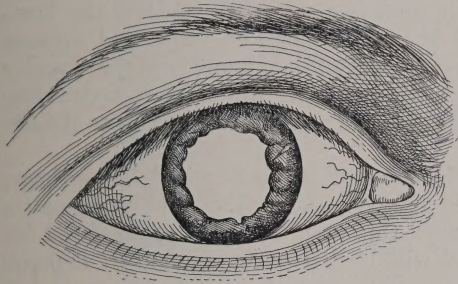


FIG. 232.—Radial laceration of the iris (Harlan).

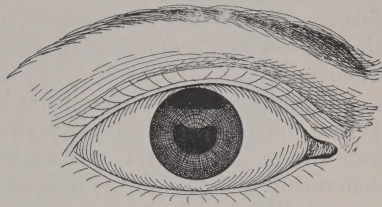


FIG. 233.—Iridodialysis.

Traumatic coloboma in connection with rupture of the sclera should not be mistaken for *retroflexion of the iris*.

In *iridodialysis* the rent is easily discerned, unless very small and hidden by the opaque limbus corneæ. The portion of the iris detached retracts toward the centre of the pupil, and the latter loses its circular form and becomes somewhat kidney-shaped (Fig. 233). With the ophthalmoscope the fundus-reflex can be seen through the new opening as well as through the pupil.

Treatment.—Very little can be done to remedy most of these lesions. Dr. Eugene Smith¹ of Detroit has suggested that iridodialysis be corrected by making a small incision at the corneo-scleral junction at the place of the detachment, and by means of iris-forceps catching the edge of the iris and drawing it into the incision. It is usually held in place by the compression of the lips of the wound; but if this be not sufficient, it may be attached by a delicate suture to the neighboring conjunctiva. Before attempting this operation all irritation from the original injury must have subsided.

Displacements of the Iris: Retroflexion and Anteversion.—

Both *retroflexion* and *anteversion of the iris* are very rare. In *retroflexion* a part, sometimes the whole, of the iris is thrown backward, so as to lie against the ciliary body. The pupillary portion alone may be thus displaced, or it may carry with it the whole width of the membrane. It occurs almost exclusively in cases where the lens has also become displaced. Only a part of the circumference of the iris is implicated in most cases, and this part becomes invisible, the appearance being much like that of an iridectomy. When the whole iris has thus receded the appearance is that of aniridia.

In *anteversion* a portion of the iris is torn from its periphery (iridodialysis), and the loosened segment is twisted upon itself or turned over so that its posterior surface is directed forward. The exposure to view of the pigment-surface of the iris and the partial or complete obstruction of the

¹ *Journal of the American Medical Association*, Sept., 1891.

pupil, together with the traumatic opening of the iridodialysis, determine the existence of this double lesion.

These displacements call for no treatment, unless the vision be interfered with in anteversion by the detached membrane lying across the pupil, when it may be excised by an iridectomy.

Contusion-injuries of the Ciliary Body.—These undoubtedly may occur, but outside of such as accompany rupture of the sclera their existence is always difficult to ascertain and their diagnosis is doubtful.

Contusion-injuries of the Choroid.—These are hemorrhage, detachment, or rupture.

Hemorrhage may take place beneath the choroid, into its substance, or into the vitreous humor. In itself it obstructs the visual field, either as a whole or in sections, according to its extent and situation. When the hemorrhage is in or beneath the choroid it may be small or large, and appears with the ophthalmoscope as a bright-red spot of irregular, oval, or circular form. The retinal vessels pass over it without interruption. In extravasations into the vitreous humor the conditions and appearances are those already described.

Detachment of the choroid is but the effect of a subchoroidal hemorrhage. It disappears with the absorption of the blood, and unless it is very small a long time will be required to accomplish this result. Spots of localized degeneration and atrophy of the choroid will be left with pigmentary deposits around them (see also page 357).

Rupture of the choroid is usually single and situated between the optic disk and macula lutea, and the retina is seldom involved. It is generally curved and runs vertically, its concavity being toward the optic disk. It varies in width from one-third to one-half the diameter of the optic disk, tapering toward its extremities, and in length from one to four diameters. Exceptionally, there may be more than one rupture, or it may be branched and its direction may be oblique or horizontal.

The rupture cannot be seen until the blood, which has generally been effused into the vitreous humor, has been absorbed. It is then shown by the ophthalmoscope as a more or less sharply defined rent, at first yellowish with red margins, and later white with pigmented margins, and with retinal vessels passing unbroken across it (consult Plate 3, Fig. III.). *Detachment of the retina* sometimes follows cicatrization of a ruptured choroid.

In rupture of the choroid vision is at first much reduced or lost. After two or three weeks sight begins to return, but it is seldom fully regained. There is always left a scotoma corresponding to the rupture, and metamorphopsia is a common sequence (see also page 357).

Concussion-injuries of the Retina.—A blow on the eye may cause hemorrhage, rupture, detachment, so-called “commotion,” or pigmentation of the retina.

A *retinal hemorrhage* is easily recognized by its elongated, irregular shape, by the break of continuity of a retinal vessel, and, if near the macula lutea, by a disturbance of vision and scotoma. The edges of the rent are ragged and the choroidal vessels are sometimes exposed. Whitish cicatricial lines, bordered with pigment, are seen later (Fig. 234).

“*Commotio retinæ*” is a term used to designate a peculiar effect characterized by edematous swelling and opacity of the retina, usually at the posterior part of the eye at a point opposite to that struck. It begins an hour or two after the injury in disseminated patches as grayish or dotted opacities. These gradually coalesce and become more dense, until there is

one continuous, whitish, and even brilliantly white surface of ten to twelve optic-disk diameters. This opacity is at its height in twenty-four to twenty-six hours, and usually disappears in two or three days. There may be retinal hemorrhages, and the retina may be ruptured or fissured, but its vessels are not hidden by the opacity.

The vision is much reduced or abolished at first. It improves for a short time rapidly, but afterward slowly. The central part of the field is that principally affected, and there seems to be no relation between the state of vision and the extent or depth of the opacity. The vision is further dis-

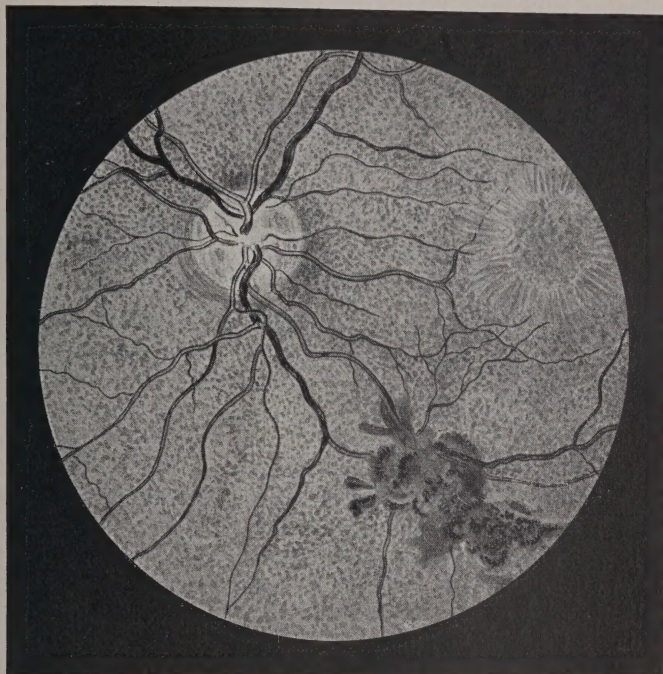


FIG. 234.—Ophthalmoscopic appearance of traumatic rupture of the inferior temporal vein (Oliver).

turbed by astigmatism caused by irregular spasm of the ciliary muscle and iris.

Detachment of the retina from a blow is not different in character and symptoms from that due to other causes (page 428).

Pigmentation of the retina is another result of contusion, and *choroiditis*, in all particulars resembling the exudative variety of this disease, may have the same origin (see also page 354).

Treatment.—In all these lesions the eye should be shaded and given rest. Atropin should be instilled when there is evidence of spasm of the iris or ciliary muscle. Detachment of the retina is to be treated like the non-traumatic form of the disease (see page 430).

Contusion-injuries of the Crystalline Lens.—Contusion of the eyeball may cause rupture of the zonula, dislocation of the lens, rupture of the anterior or posterior capsule of the lens, with opacity, or there may be opacity of the lens without rupture of its capsule.

Rupture of the Zonula.—This occurs usually in connection with dislocation of the lens. There is loss of accommodation and an increase of the

refraction of the eye. The anterior chamber is sometimes deepened and the iris tremulous.

There is no remedy for this lesion.

Dislocation of the Lens.—The lens may be dislocated in different directions and degrees. In rupture of the sclera it may be expelled or lodged beneath the conjunctiva. It may be tipped or turned on its equatorial plane, or thrown partly through the pupil and there held by the sphincter of the iris, or it may be completely displaced forward into the anterior chamber or backward into the vitreous humor. In all cases the zonula is ruptured and the lens sooner or later becomes opaque (Figs. 235 and 236).

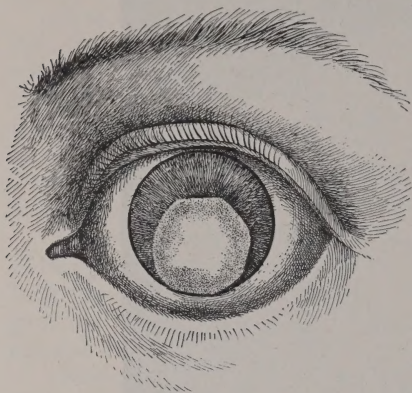


FIG. 235.—Dislocation of lens into the anterior chamber of highly myopic eye (de Schweinitz).

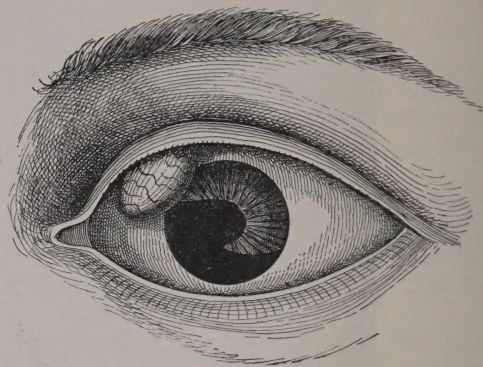


FIG. 236.—Subconjunctival dislocation of the lens (de Schweinitz).

Symptoms.—In partial dislocations vision becomes greatly impaired by the irregular refraction of the margin or the obliquity of the lens, or by its opacity. When the lens is dislocated into the anterior chamber and remains transparent the refraction is increased and the vision is myopic. When it is completely displaced into the vitreous humor the refraction is diminished and the vision is that of an aphakic eye.

A transparent lens in any position when seen with the ophthalmoscope gives a reddish or yellowish reflex through its body, while its margins, if they can be seen, are dark or quite black. When in the anterior chamber these appearances are intensified, and it is seen as a pale, yellowish, or "pale-wine yellow" pellucid body with a brilliant reflection from near its edge of a golden luster. When the lens is opaque it is shown both by the ophthalmoscope and oblique illumination as a rounded, smooth, dark or gray body, sometimes becoming quite white. In the anterior chamber it generally causes much irritation, and sometimes severe inflammation, with increased tension and loss of vision. In the vitreous humor it causes a deepening of the anterior chamber and the iris becomes tremulous. Sometimes it is fixed in the bottom of the vitreous humor, and sometimes it moves about. It may remain in this position without doing harm for a long time; but generally, sooner or later, it causes *glaucoma*, *cyclitis*, and other secondary diseases, and even *sympathetic inflammation*.

Treatment.—A lens dislocated under the conjunctiva may be left to disintegrate and absorb, or it may be removed through an opening in the conjunctiva.

In a partial dislocation an iridectomy may be made when the margin of the lens lies in the axis of vision. When the lens is incarcerated in the

pupil or it becomes opaque, it may be proper to dispose of it by discission or extraction, according to the age of the patient.

When the dislocation is into the anterior chamber, an effort may be made to reduce it by gentle pressure or rubbing over the cornea, either with or without a scleral incision behind the ciliary body to diminish the tension.

Should reduction be impossible and much irritation or inflammation be present, the lens should be extracted through a corneal incision. It may be supported during the operation by the "bident" of Agnew.

A lens dislocated into the vitreous chamber need not be disturbed unless irritation or inflammation take place, and then attempts may be made to extract it. This, however, is an uncertain procedure, especially with a floating lens, which it is almost impossible to "fish" out.

In any form of dislocation of the lens its extraction is necessarily followed by loss of vitreous humor (see also page 582).

Rupture of the Capsule of the Lens.—When the capsule is torn, whether anteriorly or posteriorly, the lens gradually becomes opaque. The rapidity with which this takes place depends upon the size of the rent. In some cases, where the latter is very small, it closes and heals, and the opacity remains partial. To the symptoms of *cataract* are added those of the irritant effects of swelling of the lens or the exuding of its substance into the aqueous humor.

The pupil should be kept as widely dilated as possible by atropin, and the lens should be extracted when its swelling causes dangerous reaction.

Contusion of the Lens.—The lens may be bruised or contused without rupture of its capsule. It is followed by opacity, with all the symptoms of non-traumatic cataract.

The treatment is that of spontaneous cataract.

Penetrating Wounds of the Eyeball.—Penetrating wounds of the eyeball are generally situated in its anterior part, and most frequently in the cornea or corneo-scleral junction. They assume great varieties of form, size, and shape, some being so small as scarcely to be traced, and others so extensive as to destroy a large portion of the eyeball. They may be limited to the cornea or sclera alone, or they may extend deeper into the iris, lens, and the structures beyond, and even pass through the eye into the orbit.

Symptoms.—The symptoms vary with the nature and depth of the wound. When the penetrating object is small only a minute corneal opacity or abrasion or an opacity of the lens will mark its course. But when a wound is of larger size it is readily seen; the evacuation of a portion of the intraocular fluids causes the eyeball to become softened, and there may be prolapse of the subjacent structures. Hemorrhage into some part of the eye usually takes place. Careful examination should be made for rents in the iris, opacities of the lens, and lesions in the fundus when the parts are not obscured, using the ophthalmoscope and oblique illumination for this purpose.

The effect of penetrating wounds upon the state of vision depends upon the nature of the lesions present. These may be so slight as not to disturb vision at all, or, if disturbed, only for a brief time; or they may be so extended that the vision is totally and permanently lost. Very little, if any, pain is experienced, unless inflammation develops.

In all penetrating wounds there is great danger of infection, and inflammation, with or without suppuration, is therefore a frequent sequence. An exuding and swollen lens is also a potent cause of iritis and cyclitis.

Prognosis.—The prognosis depends very much upon the situation and nature of the wound. Opacities of the cornea and lens may obstruct vision,

and injury of the retina in the macular region, very large hemorrhages, or great loss of vitreous may at once destroy it. An inflammation of the iris and ciliary body, caused by a wounded lens, is very liable to lead to obstruction or closure of the pupil and softening and shrinking of the eyeball. Punctured, ragged, or gaping wounds of the ciliary body are always serious, and they especially predispose to inflammation of the fellow-eye (page 347).

Treatment.—In all cases the strictest antisepsis should be observed. The wound should be freed of all included structures by excision or replacement, made scrupulously clean, and, whenever possible, closed by sutures and conjunctival flaps. When sutures cannot be used the lips of the wound may often be approximated or completely closed by a compress-bandage over the eye.

Hemorrhages and inflammatory reaction are to be treated as elsewhere indicated. In some cases it is best to perform an iridectomy and extract a wounded and swollen lens. This will sometimes save the eye, but it more often fails. On this subject that master of ophthalmology, Arlt, has said: "Such removal of the lens is to be considered more as a doubtful remedy, as we seldom succeed in removing the lens as a whole, or even its greater part, and thus do not obviate the dangers of mechanical irritation or of increased pressure; perhaps, indeed, we even increase them."

The causes of sympathetic inflammation not usually being operative during the first two or three weeks, an effort may be made in some cases to save the wounded eye. Should improvement be rapid during this period, should no symptoms of cyclitis appear, and especially should there be promise of serviceable vision, such effort may be continued, but always with a great deal of caution. On the other hand, should cyclitis of the injured eye develop and continue, and especially should vision be hopelessly lost, enucleation or evisceration should be performed before the expiration of three weeks.

There are cases in which the eye is so seriously wounded that no attempt should be made to save it, but enucleation or evisceration should be done without delay.

Foreign Bodies on the Conjunctiva and Cornea.—Minute bodies of various kinds may become lodged on the conjunctiva beneath the lids (usually the upper one near the center), or on the cornea, becoming imbedded in its epithelium. When the force is sufficient, as in explosions, they may be driven deeply into the corneal substance.

A foreign body on the conjunctiva alone is scarcely felt, but when on the cornea or rubbing against it, it produces a scratching or pricking pain, which is not usually severe. There is considerable lachrymation and the eye becomes red. If the body is not removed soon, it may excite inflammation, particularly if it is on the cornea. In the latter case also it may cause ulceration of the cornea at the point where it is lodged. This sometimes extends and causes destruction of the eye.

The foreign body is detected by careful inspection, aided, if necessary, by oblique illumination.

Treatment.—A body which is not imbedded deeper than the epithelium of either the conjunctiva or cornea should be picked away with some sterilized, sharp-pointed instrument. When one is driven into or beneath the ocular conjunctiva, it may be excised, taking with it the least possible amount of this membrane. When it is imbedded in the substance of the cornea, it should be picked out with as little injury as possible to the surrounding tissue. It is generally impossible to remove *grains of powder* in this way,

and they can be allowed to remain without danger of ulceration or suppuration. They simply leave black stains. Dr. Edward Jackson of Philadelphia has suggested burning them out with a galvano-cautery point. But such a point must be very small and used with great care, or the effects of the burn will be worse than those of the powder. It should not be forgotten that more than one body may be present at the same time.

Foreign Bodies within the Eyeball.—Any small, hard object, such as a splinter of wood, scale of iron or steel, spicule of brass or copper, fragment of stone or glass, may be projected with sufficient force to penetrate the coats of the eye and become lodged at any point within them. It usually enters through the anterior part of the eye, and most frequently through or very near the cornea.

Symptoms.—The symptoms are essentially those of a penetrating wound, to which are added such as are caused by the presence of the foreign body. The latter are at first negative, but later unusual irritation and inflammation develop, with corresponding symptoms.

Diagnosis.—The history of the accident is of great importance. The circumstances under which it happened, the occupation engaged in, the small size of the object striking the eye, the direction of its course, whether or not it was seen after striking the eye, the immediate effect on vision, and kindred information, should be ascertained, if possible. Unfortunately, such information is often very incomplete.

If, at the time of an explosion of a percussion-cap or the discharge of a shot-gun, or while hammering iron or steel or cutting stone, a small object that was not afterward seen has struck the eye and perforated the cornea or sclera, the probability that it has entered the eye is so strong as to become almost a certainty. The reason of this is apparent when it is remembered that the resistance of the intraocular fluids is not sufficient either to check the course of the body or to cause it to rebound, and a force which was great enough to cause it to cut through the tough, outer coat would carry it farther into the eye after the opening was made.

With such a history and the presence of such a wound most careful search should be made for a foreign body. Hemorrhages, corneal irregularities, and opacities of the lens or vitreous humor greatly obstruct the examination; but when the media are not obscured, and when the object is not hidden by its position or by exudates, the ophthalmoscope and oblique illumination will often convert the suspicion of its presence into a certainty. A metallic object in the vitreous chamber gives a lustrous reflection when seen with the ophthalmoscope.

When, from any cause, a foreign body cannot be seen, it may in rare instances, if of considerable size and near the surface, be felt by a probe; but this should be used with great caution.

When the body is steel or iron the *electro-magnet* will often assist in diagnosis. A strong one applied to the surface of the eyeball will sometimes attract the iron or steel, and the movement of the latter will cause more or less pain. Or, if the wound is so situated as to warrant it, an extension-point of the electro-magnet of suitable size may be carefully introduced into it, when it will sometimes not only attract the body to the surface, but bring it out.

The special adaptation of Röntgen's rays, or skiagraphy, to the eye will oftentimes demonstrate the presence of a foreign body and also its approximate position (see Appendix, pages 607-611).

Should it be impossible by means of sight, touch, the electro-magnet, or

skiagraphy to ascertain the presence of a foreign body beyond doubt, the presumptive diagnosis of its presence based upon the history and conditions above outlined should prevail. In case of delay such symptoms of irritation and inflammation may set in as could scarcely be expected as a result of the wound alone. These will strongly corroborate the other evidence of the presence of a foreign body. The eye may, however, remain quiet in exceptional cases, but this is not sufficient to outweigh the primary evidences and to nullify the diagnosis of a foreign body in the eye.

Prognosis.—When a foreign body is lodged in the eye the consequences of a penetrating wound follow which have already been considered, together with those arising from the presence of the foreign body itself.

As regards the latter, it may be said that, however small the body may be, whatever may be its substance, and wherever it may be situated, it sooner or later, with rare exceptions, causes destructive inflammation of the injured eye, and may also induce sympathetic inflammation of the other. The only structure which will tolerate a foreign body without danger of inflammation is the lens. Even here vision is obscured by the lens becoming opaque.

Cases have been recorded in which the membranes of the eye or the iris have tolerated a foreign body for a long period of time, or in which one has become encysted and remained harmless, or in which one has been spontaneously expelled; but they are so rare as not to have material weight in prognosis or treatment. In every case it should be assumed that the eye is sure to be lost unless the offending body is removed. After its removal the eye is in the condition of one with a penetrating wound, and may or may not be saved according to the circumstances of the case.

Treatment.—In some cases, although the foreign body may be found and removed, the injury is so extensive that the eye is hopelessly lost. Immediate enucleation or evisceration is then the safest procedure. But when the nature of the injury will permit, all reasonable effort should be made to remove the foreign body and save the eye with as much vision as possible.

When the presence and location of a foreign body have been determined, the course to pursue will depend on what substance it is and on its position. If situated in the anterior chamber or iris, it may be extracted with or without excising a piece of iris through an incision at a suitable point in the cornea. If lodged in the lens, it may be left there until the latter has become fully opaque, and then both may be extracted together. Or, should the wounded lens become absorbed, the foreign body may then be treated as if it were, from the first, lodged in the anterior chamber or perhaps in the vitreous humor.

When a body is lodged in the posterior part of the eye it may sometimes be caught by forceps (without teeth), hooks, or scoops, and drawn out. But such a happy result is not often obtained.

Should the foreign body be steel or iron, the *electro-magnet* (Fig. 237) is of great service, and the chances of extracting the fragment are increased many fold. Very large and powerful electro-magnets, which have lately been introduced by Haab, are not often available, and the smaller instruments give eminent satisfaction. The electro-magnet should be armed with as short, and also as large, an extension-point as can be consistently introduced, since the attractive force is diminished very rapidly as the point becomes smaller and longer. The point should also be flattened or squared, instead of rounded, to give as much surface-contact as possible. A rounded point reduces this to a minimum.

The extension-point may be introduced through the original wound, or,

which is often preferable, through an incision suitably located and made for the purpose. It should be carried, without twisting it or changing its course, toward the supposed or known position of the fragment and reintroduced if necessary. Should it attract the steel or iron or in any way come in contact with it, it will generally produce a distinct click which can be both felt and heard. On withdrawing the point the steel or iron is brought out with it, or perhaps it is held back at the wound, when the point should be partially reintroduced, and the extraction then assisted by forceps made of some other material than iron or steel.

After removal of the foreign body the case becomes one of a penetrating wound of the eye, and should be treated accordingly.

Should it be impossible to remove a foreign body whose presence is extremely probable or definitely determined, the vision being without doubt permanently lost, the eye should be enucleated or eviscerated. A delay, however, may be made for a short time, as in penetrating wounds, when there remains some vision and the diagnosis is doubtful. Rapid improvement and absence of symptoms which point to sympathetic disease may justify still further delay, but with a continuance of inflammatory symptoms and a progressive deterioration of sight, if this was not destroyed at first, the delay

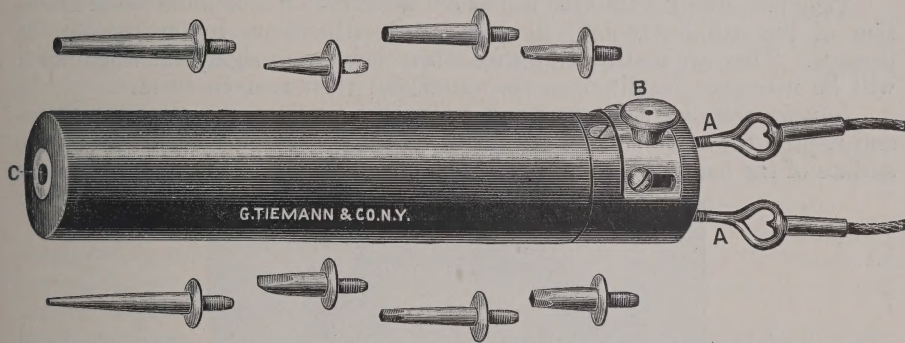


FIG. 237.—Hubbell's electro-magnet, actual size: *A, A*, ends of cords connecting the magnet with a galvanic battery; *B*, slide for opening and closing electric circuit; *C*, end of core tapped to receive the extension-points. The extension-points, a few of which are shown, may be of any desired length, shape, curve, or size.

should not extend beyond two or three weeks, as after this time sympathetic inflammation becomes imminent at any moment.

Injuries of the Eyelids and Lachrymal Passages.—*Echymosis of the eyelids* follows contusions and wounds, and also hemorrhages into the orbit and around the eyeball. The discoloration of the skin varies in depth and extent with the amount of blood extravasated. There is, occasionally, swelling of the parts and a feeling of stiffness, but no pain. The blood is absorbed, and the skin regains its normal color in from one to three weeks.

Very little treatment is necessary. Absorption of the blood may be hastened by bathing the parts with water as hot as can be borne and by gentle frictions.

Emphysema of the eyelids may take place when the mucous membrane of the nose becomes torn in connection with a fracture or injury involving the nasal cavities, and a communication is established between the latter and the cellular spaces of the lids, and air is forced into them by blowing of the nose. The parts are immediately puffed up into a soft, crepitating, and painless swelling.

The patient should be cautioned against further blowing of the nose till

after the wound is healed. A compress-bandage should be applied over the lids, and the air will be absorbed in a few days.

Contusions of the lids are generally followed by ecchymosis with some swelling and soreness. They should be treated by cold applications, unless suppuration takes place, and then warm fomentations should be used, and the abscess opened early by incision.

Punctured wounds are generally of little consequence, but the *incised* and *lacerated* varieties, especially the latter, require careful attention. When a wound runs parallel with the edge of the lid it will unite without deformity. But when it extends across the orbicularis muscle or through the margin of the lid, the wound gaps, and if not closed by surgical measures leaves a depression of the surface or a permanent cleft through the edge of the lid. When the lachrymal canals are severed they become permanently closed.

The utmost care should be taken to close all gaping wounds and to restore to proper position displaced parts. The loss of skin may call for a plastic operation. When a lachrymal canal has been severed, it should, if possible, be searched for and slit up and kept open.

Foreign bodies may become lodged beneath the skin, and should be removed by cutting down upon them and picking them out.

They may also get into the lachrymal punctum or canal, and cause irritation of the ball by rubbing against it, or stillicidium by obstructing the passage. They are easily withdrawn when they are in sight, but when not it will be necessary to slit open the canal and then remove them.

Injuries from hot substances and escharotics produce the same symptoms and require the same general treatment as those occurring elsewhere on the surface of the body (see Fig. 238). The unsightly and distressing deformity

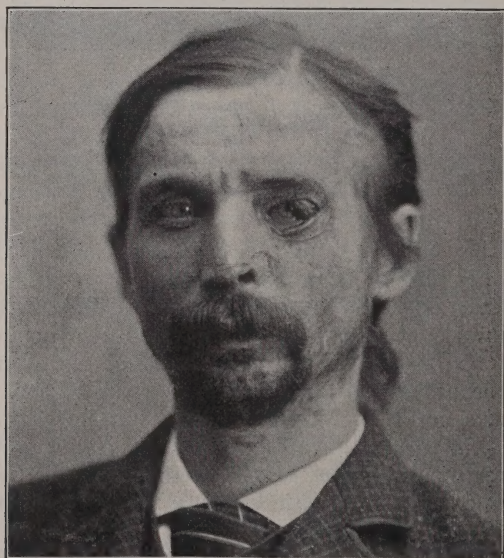


FIG. 238.—Ectropion following a burn.

and loss of function which follow cicatrization should be prevented by skin-grafting, preferably by Thiersch's method. To this end, as soon as the eschar is thrown off and the granulating process is well established, the affected surface should be scraped, and the grafts applied as described in surgical treatises. This part of the treatment cannot be too forcibly urged.

GLAUCOMA.

By J. A. LIPPINCOTT, A. B., M. D.,

OF PITTSBURG, PA.

General Considerations.—The term “glaucoma” is applied to a group of phenomena, the most prominent of which, apart from a greater or less degree of impairment of vision, are an increase in the *hardness of the eyeball* and an *excavation in the head of the optic nerve*. Brisseau in the last century and Weller and Mackenzie early in the present directed attention to the first of these two characteristics, the great English observer especially dwelling on its importance and systematically employing a rational method of relieving it—viz. puncture of the sclera and of the cornea.

To determine the pressure and degree of abnormal tension palpation is employed in the manner described on page 170. A number of *tonometers*, or mechanical substitutes for the fingers, have been devised, but, owing to defects which are possibly irremediable, they are not in general use.

In recording the results of palpation of the globe the method usually employed is that suggested by Bowman, according to which T. stands for normal tension; T. + ? tension probably increased; T. + 1 and T. + 2 still higher degrees; while T. + 3 indicates stony hardness. Care is required not to mistake the rigidity of a thickened eyelid or that of an abnormal sclera for an actual increase in intraocular tension. In doubtful cases the finger-tips may be placed on the naked eyeball. In investigating ocular tension the *tactus eruditus* is an essential qualification, and no opportunity of acquiring it should be neglected.

The *excavation of the optic nerve* in glaucoma involves the whole or nearly the whole surface of the disk, and attains a considerable depth. Its sides are steep or even undercut, so that the cavity is ampuliform—*i. e.* bulging in its deeper portions.

Viewed with the ophthalmoscope, the blood-vessels are crowded toward the nasal side, and, as they dip into the pit, make a sharp bend, and frequently disappear behind the overhanging margins. When they reappear on the floor of the excavation they are less distinct and lighter in color, and their continuity is apparently broken, owing to *parallactic displacement*. From the same cause they appear to move more slowly in response to lateral movements of the object lens used in the indirect examination than they do

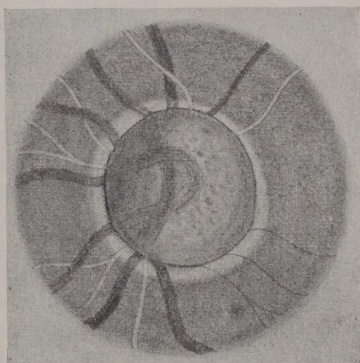


FIG. 239.—Glaucomatous excavation.

at the level of the retina. On making use of the direct method a stronger concave or weaker convex lens is required than the one used for the neighboring retinal surface. This difference in refraction constitutes a means of accurately measuring the depth of the excavation, an interval of three diopters corresponding to about 1 mm.

Arterial pulsation is either spontaneous or is easily induced by light pressure with the finger. This phenomenon is a result of the increased intraocular pressure, which is sufficient to retard the arterial current, except when the latter feels the onward thrust of the cardiac systole. The blood thus enters *per saltum*, instead of continuously as under normal conditions. Spontaneous *venous pulsation* is common.

The disk shows a bluish or greenish pallor, and is surrounded by a more or less complete ring, which sometimes appears yellow, probably by contrast with the color of the disk. This ring is due to atrophy of the choroid and is known as the *glaucomatous halo* (Fig. 239). A *low-grade neuritis* is commonly to be detected in the nerve-head containing the pathologic excavation.

In common with most of the symptoms in glaucoma, the cupping of the optic disk is a consequence of the increased intraocular tension, the latter

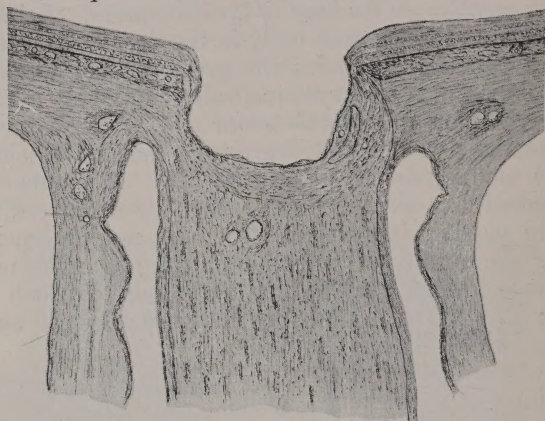


FIG. 240.—Glaucomatous excavation, microscopic section.

taking most effect at the least resisting portion of the ocular envelope—viz. the lamina cribrosa. It is probable that the process is favored in many cases by inflammation with softening and, later, cicatricial contraction of the tissues in this region; and this factor would appear to be sometimes sufficient in itself to produce an excavation indistinguishable ophthalmoscopically from one known to result from abnormally high pressure (Fig. 240).

Varieties of Glaucoma.—Glaucomatous manifestations range themselves in three principal groups:

(I.) Primary glaucoma, the pathology of which is not positively determined.

(II.) Secondary glaucoma, which obviously depends upon some pre-existing morbid condition.

(III.) Congenital glaucoma, usually described as buphthalmos.

I. Primary Glaucoma.—This variety, which may or may not exhibit signs of inflammation or congestion and is subdivided accordingly, will be first described.

Etiology.—The *predisposing* causes of glaucoma have reference to age, sex, race, systemic condition, and the conformation and refraction of the eye.

It is rare in the young,¹ and most frequent in the fifth and sixth decades of life. More women than men suffer from *inflammatory glaucoma*, whereas more men than women are affected with the *non-inflammatory* form of the disease. In the analysis made by William Zentmayer and William Campbell Posey of 167 cases of *glaucoma simplex*, men were found slightly more liable than women. The extremes of age noted were thirteen and ninety-six years. These facts are represented graphically by these authors in the following diagram. A disproportionate number of cases are seen in the Jewish race

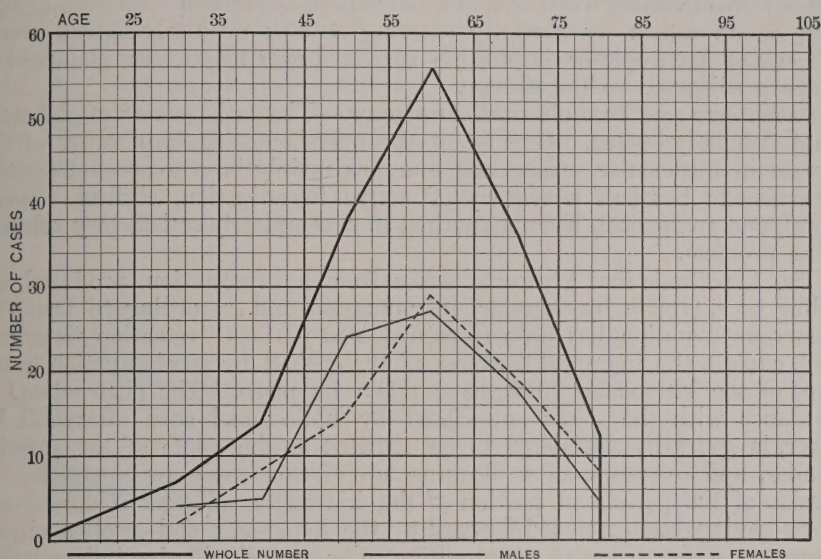


FIG. 241.—Chart showing the relationship of glaucoma simplex to age and sex (Zentmayer and Posey).

(Knapp), and Egyptians are said to be peculiarly liable. There appears to be a tendency to hereditary transmission. When this is the case the period of life at which the outbreak occurs is earlier in each succeeding generation (De Wecker). The gouty and rheumatic diatheses favor the development of the malady, and those who suffer from arterial sclerosis, chronic bronchitis, or heart disease are liable to the disease. A causal relationship between influenza and non-inflammatory glaucoma has been recorded. The author has observed catarrhal disease of the nasal passages in a large proportion of cases of inflammatory glaucoma. Small, hyperopic eyes are more likely to be affected than emmetropic or myopic eyes. This is explained by the limited circumlental space due to the hypertrophy of the ciliary muscle in hyperopia, and also to the excessive and practically continuous contraction of this muscle in accommodation.² The progressive increase in the diameter of the lens throughout life noted by Priestley Smith is claimed by this author as an important etiological factor. There is a relation between

¹ According to Priestley Smith, not 1 per cent. of the cases begin earlier than the twentieth year. A few, generally monolateral, cases are seen in children.

² Zentmayer and Posey's figures in regard to the refractive condition of the eye in their 167 cases are as follows:

Hyperopia = 140 eyes;
 Myopia = 28 eyes;
 Emmetropia = 21 eyes.
 Twenty eyes were astigmatic.

smallness of the cornea and glaucoma (normal average horizontal diameter, 11.6; glaucoma, 11.1).

Among the *exciting causes* may be mentioned various emotions—joy, grief, anxiety, etc.—producing ciliary congestion, and the incautious use of mydriatics, which, by thickening the peripheral portion of the iris, directly diminish the filtrating area in the anterior chamber. An onset of the disease has been precipitated by exposure to cold, by loss of sleep, worry, neuralgia, and by the ingestion of a hearty meal. Nettleship relates a case which was always worse in warm weather, and a lady under the author's care can always bring on an attack by abruptly entering a dark or dimly-lighted room. Over-use of ametropic or improperly corrected eyes may excite glaucoma in an eye predisposed to the disease.

Pathology and Pathological Anatomy.—The pathogenesis of glaucoma is not definitely settled. Because of the overshadowing importance of the increase in intraocular tension the aim has mainly been to account for this phenomenon; but half a century of active investigation, clinical, experimental, and anatomical, has not resulted in a completely satisfactory solution of the problem.

The hypothesis that glaucoma arises from hypersecretion, produced, according to v. Graefe, by choroidal inflammation, and, according to Donders, by nervous irritation, has been discarded, and various "retention theories," which explain the increased hardness of the eyeball by an obstruction to the escape of the intraocular fluids, have taken its place. The obstruction, in accordance with the views enunciated by Knies, and soon afterward by Weber, is generally considered to be situated at the angle of the anterior chamber, and to consist in a blocking up of this angle by apposition or adhesion of the peripheral portion of the iris to the adjacent sclero-cornea, the iris having been crowded forward by the hyperemic and swollen ciliary processes. Knies believed the condition to be one of adhesive inflammation of the iris periphery, while Weber regarded this adhesion as secondary to pressure. In his most recent communication on the subject Knies makes a sharp distinction between *glaucoma simplex*, which he conceives to be an *optic nerve-atrophy with excavation*, and *true forms of glaucoma*, which should be considered as an *irido-cyclitis anterior*—an inflammation which may occur in varying degrees of intensity. It has been demonstrated by Leber and others that the ciliary region constitutes the principal outlet for the lymph-current, which, starting at the ciliary processes, proceeds forward through the zonula and pupil into the anterior chamber, and thence through the pectinate ligament into the canal of Schlemm, from which it finds its way into the venous system. In the cases in which the iris occupies its normal position it is possible that filtration may be hindered by serosity of the liquids (Priestley Smith) or by a choking of the meshes of the pectinate ligament with pigment-cells from the ciliary processes and the posterior surface of the iris (Niesnamoff).

Priestley Smith, as already intimated, thinks that an important element is a narrowing of the circumlental space, due to a senile increase in the size of the lens or to a small ciliary circle as seen in hyperopic eyes—hence a forward displacement of the lens and blocking up of the excreting angle.

Stilling's view, that glaucoma may be produced by tissue-changes which tend to hinder the exit of fluids by way of the optic-nerve entrance, may have a limited field of application, as may also that of Rheindorf, who claims that the obstacle to the nutritive current consists in a sclerosis of the lenticulo-zonular diaphragm. Laqueur and others think that glaucoma depends

upon obstruction of the intraocular lymphatics, which find their way out with the vena vorticiosa.

The anatomical conditions which have been observed in glaucomatous eyes are, among others, the following: (1) Edema, and at a later stage ulcerative processes in the cornea. (2) Scleral changes, including rigidity, fatty degeneration, and equatorial staphylomata. (3) Obliteration (with or without adhesive inflammation) of the angle of filtration, of the spaces of Fontana, and of the canal of Schlemm (Fig. 242, A). (4) Atrophy of the iris, chiefly of the external layers, with destruction of the vessels. (5) Sometimes swelling and sometimes atrophy of the ciliary processes. In the latter case these bodies shrink backward, and frequently leave the iris in contact with the cornea (Fig. 242, B). (6) Glaucomatous cataract—*i. e.* cataract which is a direct result of the disease. (7) Fluidity of, and opacities in, the vitreous. (8) Marks of choroidal inflammation, such as atrophy and loss of elasticity of the choroid, and periphlebitis with reduced lumen of the veins, especially the vasa vorticiosa. (9) Destruction, partial or complete, of one or more of the retinal layers and detachment of the retina. (10) Lastly, the excavation of the

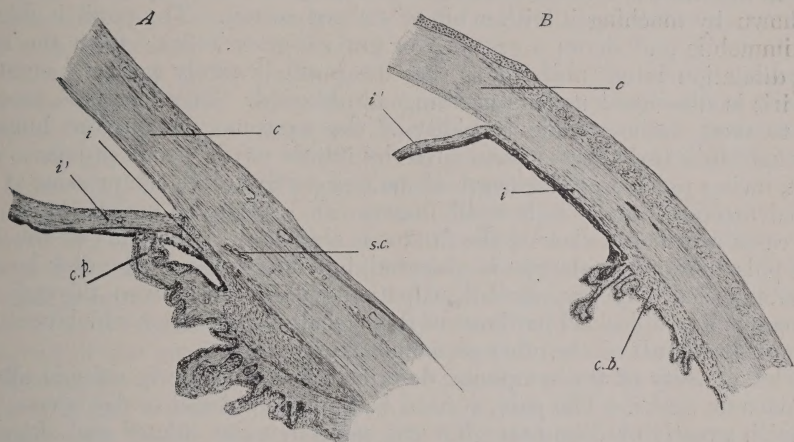


FIG. 242.—A, absolute glaucoma: *c.* cornea; *s. c.* Schlemm's canal, partially closed; *i.* iris adherent to sclera and closing angle of filtration; *i'*, free portion of iris; *c. p.* ciliary process, reaching forward and in contact with iris. B, absolute glaucoma at a more advanced stage; *i.* iris extensively adherent. Schlemm's canal is entirely obliterated. The ciliary body and processes are decidedly atrophied.

optic nerve, which may or may not show traces of a low-grade neuritis.¹ The precise relation of the changes just enumerated to the glaucomatous process cannot in the present state of our knowledge be dogmatically stated. Some of them are probably etiological factors, while others are doubtless results of the continued pressure.

Primary glaucoma may be *inflammatory*, or *simple i. e. non-inflammatory*.

Inflammatory or congestive glaucoma (glaucoma irritatif) is classified as (a) *acute*, (b) *subacute*, or (c) *chronic*, according to the severity of the symptoms.

(1) **Acute Glaucoma** (*Acute Inflammatory or Congestive Glaucoma*).—(a) *Period of Incubation, or Prodromal Stage*.—The prodromal or intermittent stage is characterized by mild attacks, in which the cornea is slightly steamy and anesthetic, the pupil moderately dilated and sluggish, and the

¹ Marked hyperemia and edema of the nerve-head, which afterward becomes cupped, is an early symptom in glaucoma (Knies), and actual neuritis in primary glaucoma, usually precedes increased tension (Brailey and Edmunds).

anterior chamber somewhat diminished in depth. There is noticeable, but not pronounced, pericorneal injection, and palpation shows some increase in tension. The vision is smoky from the corneal haziness, and rainbows are seen around lights from the same cause. The ophthalmoscope may reveal pulsation of the retinal arteries, but as yet there is no cupping of the disk. When the attack is ended the eye returns to its normal condition, except that the accommodative power is apt to be lessened, the patient requiring stronger reading-glasses than before.

The stage of prodromata may last months or years, the intervals between the attacks growing gradually shorter, and may terminate in an acute attack.

(b) *Period of Attack.*—The glaucomatous attack, whether preceded or not by an intermittent stage, is suddenly ushered in by violent and excruciating pain in the eye and the corresponding side of the head, with vomiting, fever, and even loss of consciousness. The lids become edematous and the ocular conjunctiva reddened and swollen. The cornea is decidedly hazy, owing to edema of its superficial layers. The haziness is generally most pronounced in the center, and is sometimes accentuated in spots, giving a dotted appearance to the surface. Corneal sensibility is more or less completely abolished, as shown by touching it with a bit of twisted cotton. The pupil is dilated and immobile and shows a greenish or grayish-green reflex¹ from the lens. The dilatation is not uniform, so that the pupil is rarely perfectly circular. The iris is discolored and its markings are blurred. There may be, according to most authors, some turbidity of the aqueous and vitreous humors, although this turbidity is considered by others as far from proven. The sight, owing partly to the corneal edema and partly to the compression of the retinal arteries, rapidly fails until fingers can scarcely be counted. In the rare cases in which a view of the fundus is obtainable hyperemia of the disk with pulsation of the arteries is observed, but no change in the disk level is to be expected. Lastly, careful palpation will disclose, even through the edematous lids, a decided hardness of the eyeball—a condition which accounts for most if not all of the other phenomena.

The intensity of the symptoms described above begins to subside after a few days or weeks. The pain, corneal haze, palpebral and ocular edema, etc. diminish greatly or disappear; but the pupil remains dilated and sluggish, the pericorneal region somewhat injected, the anterior chamber abnormally shallow, and the vision is usually considerably reduced. Tension continues elevated. This condition is known as the *glaucomatous state* (*habitus glaucomatosus*).

After a longer or shorter period of comparative quiet another outbreak may occur, and then another, until the sight is wholly destroyed—a condition described as *absolute glaucoma*. The eye assumes a dull, expressionless look. The cornea is surrounded by a zone of livid or slaty hue. The pupil displays a border of black pigment (*ectropium uveæ*). The lens and the narrow atrophic rim of the iris are crowded against the cornea. The tension of the globe is usually excessive. The ophthalmoscope now generally reveals the characteristic glaucomatous excavation. With the advent of blindness the patient in some cases obtains surcease of suffering; in others the attacks continue until relief is afforded by surgical means.

Glaucomatous Degeneration.—After the glaucoma becomes absolute striking tissue-changes sooner or later begin to manifest themselves. The atrophied sclera succumbs to the intraocular pressure, and bluish-black swellings appear between the cornea and the equator. The lens may become

¹ Hence the name glaucoma—from *γλαυκός*, sea-green or grayish-green.

opaque (*glaucomatous cataract*). The eyeball may go on to atrophy, with detachment of the retina, and may show deep furrows in the line of the recti muscles, or the morbid process may end with sloughing of the cornea and panophthalmitis.

In some cases of acute glaucoma vision is suddenly and irretrievably lost at the first attack, constituting what is known as *glaucoma fulminans*.

(2) **Subacute Glaucoma.**—This variety presents the phenomena of the acute form of the disease in a much less intense degree, and might not improperly include the prodromal stage of that form. But, whether intermittent or continuous at the outset, it passes by insensible gradations into the third and most common variety—viz. :

(3) **Chronic Inflammatory or Congestive Glaucoma.**—The appearance of the eye in this affection is very characteristic. The dull-livid or dusky-red color of the sclera with its swollen and tortuous veins, the smoky look of the cornea, the irregular dilatation and eccentric position of the pupil, the obvious atrophy of the visible portion of the iris, the marked shallowness of the anterior chamber, and the greenish reflex from the lens, combine to form a picture which, once seen, can always be recognized. The pain, though sometimes severe, is not so intense nor is the corneal insensibility so complete as in acute glaucoma.

Central vision slowly fades, and the visual field gradually contracts, especially on the nasal side. In the later stages cupping of the disk is revealed by the ophthalmoscope. The disease, if unchecked, proceeds, as does acute glaucoma, to the establishment of absolute glaucoma, and later to one or more of the phases of glaucomatous degeneration.

II. Simple Glaucoma (*Glaucoma Simplex, Chronic Simple or Non-inflammatory Glaucoma*).—This is one of the most insidious of maladies. If untreated it usually terminates in blindness; nevertheless, at least in its early stages, it presents no external signs of the grave changes going on within the eye. After the lapse of months or years there may be slight dilatation and inactivity of the pupil and moderate distention of the anterior ciliary veins.

Increased tension, while seldom pronounced, can in most cases be detected on careful and repeated examination; but it may be entirely absent. In doubtful cases the eye should be tested at different times of the day and under various circumstances, especially after a full meal or in the condition of depression following a restless night. It should be remembered also that there is no fixed and universally applicable standard of physiological tension. A careful comparison of the two eyes, especially if one is still unaffected, will tend to eliminate doubt.

The *objective phenomena* just described may occur in attacks resembling those of the prodromal stage of inflammatory glaucoma. At such times the cornea may be hazy and its sensibility may be impaired and rainbow vision may be observed. These attacks in certain cases appear to mark a transition from the simple to the congestive form of the disease.

The *cardinal symptom* of simple glaucoma is a slow but steadily progressive failure of vision, especially peripheral vision. In some cases a good degree of central visual acuity is preserved for a long time, while the field of vision is so encroached upon that the patient, although able to distinguish fine print, may not see well enough to walk about. In such cases blindness comes on suddenly, as by the abrupt drawing of a curtain.

The *field of vision* is almost always restricted. The nasal side generally suffers most, but the limitation is very often concentric (according to Zentmayer and Posey this is the most frequent phenomenon), or the field may

assume any one of a great number of bizarre forms. Frequently sector-like defects are seen. *Scotomata* partial or total are often found. According to Bjerrum, areas of special visual acuity, taking the form of rings or segments of rings with a width of 10° to 20° , and touching the blind spot at their inner margin, are sometimes observed.

In the following visual fields the boundaries for white are represented by a continuous line, those for blue by an interrupted line, those for red by a line of dashes and dots, and those for green by a dotted line:

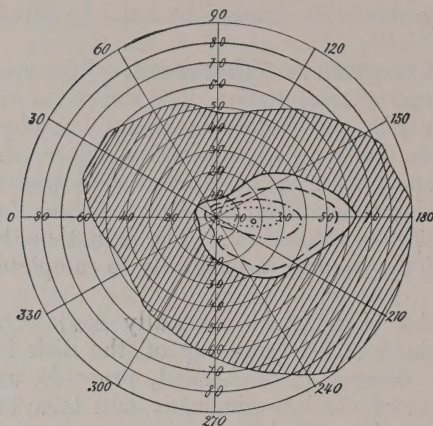


FIG. 243.—Simple glaucoma, R. E. $V = \frac{15}{XL}$.
Nasal side of field almost obliterated.

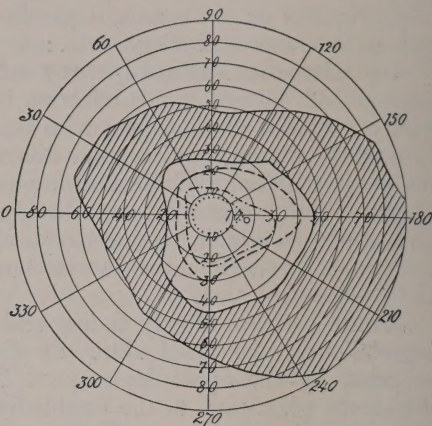


FIG. 244.—Chronic inflammatory glaucoma, R. E. $V = \frac{2}{CC}$.

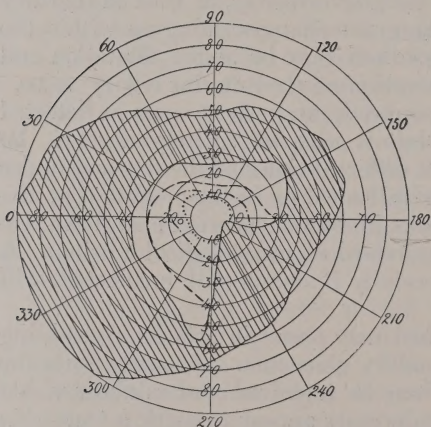


FIG. 245.—Simple glaucoma, L. E. The visual field simulates that form of hemianopsia in which one quadrant is cut out. The field of the other eye shows concentric limitation.

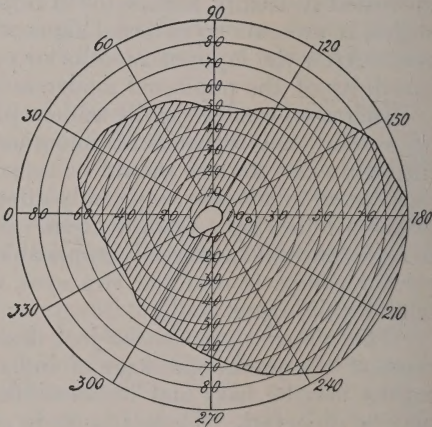


FIG. 246.—Simple glaucoma, R. E. Duration two years, $V = \frac{15}{XL}$. Fair appreciation of blue. Field of other eye still more contracted.

As a rule, the *color-fields* show no disproportionate loss. The field for blue may even be coextensive with that for form. It is also true, however, that the color-fields may be contracted, while the form-field is intact—a fact which tends to diminish the value of the evidence derived from examinations of the visual field in diagnosing between glaucoma and optic-nerve atrophy.

As in the early stages of inflammatory glaucoma, *premature presbyopia* is commonly seen.

Excavation of the optic nerve is the most striking objective, as visual impairment is the leading subjective, feature of the disease. The cupping is rarely absent when the patient presents himself for examination, which is usually after the malady has made decided progress. Furthermore, the de-

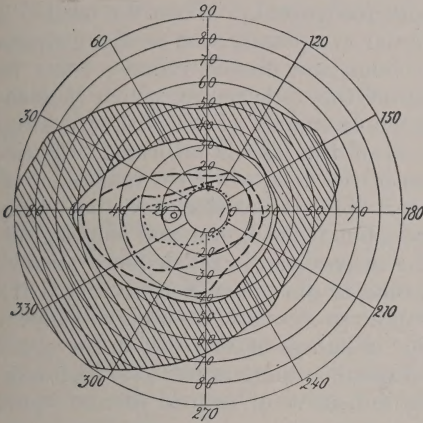


FIG. 247.—Subacute inflammatory glaucoma, L. E. Four weeks after iridectomy, $V = \frac{15}{XL}$ —. Absolute scotoma in region of "blind spot."

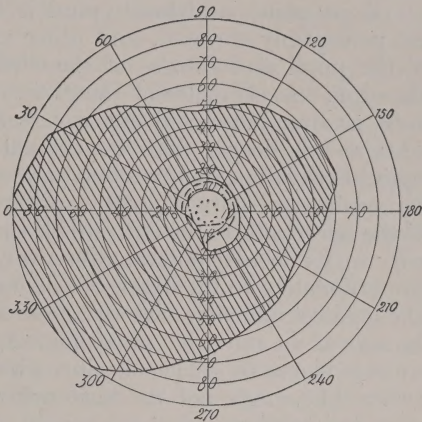


FIG. 248.—Chronic inflammatory glaucoma, L. E. Duration one year, $V = \frac{15}{XL}$ —. Patient has arthritis deformans.

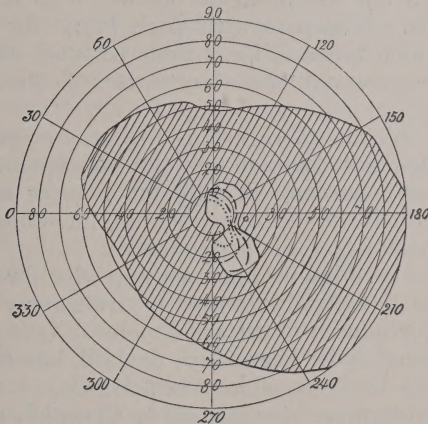


FIG. 249.—Simple glaucoma, R. E. $V = \frac{15}{C}$. Dumb-bell field. The notch on the left side was doubtless a scotoma at an earlier stage of the disease.

pression is now generally found to be characteristic, as described at the beginning of this chapter, although it is sometimes shallow (Fig. 239).

Diagnosis.—Rapidly increasing presbyopia, occasional mistiness of sight, and "rainbow vision," so frequently the harbingers of glaucomatous trouble, should arouse suspicion.

Inflammatory glaucoma has been mistaken for *iritis*. The dilated pupil and the hardness of the eyeball in the former affection ought generally to make such a mistake impossible. The pupil may, however, be bound down

by adhesions due to a previous inflammation of the iris, and the author has seen one case of intermittent glaucoma in which the pupil, though free, was of normal size. We must in such cases be guided by the history and by the other symptoms, especially the abnormal hardness of the globe. That increase of tension, rainbow vision, and shallowness of the anterior chamber are, as pointed out by Schweigger, sometimes observed in iritis, should be borne in mind, but other symptoms of iritis will then not be lacking.

Simple glaucoma when typical is easily recognized. When the tension is not perceptibly elevated, and other external symptoms, such as sluggishness of the pupil and fulness of the ciliary veins, are absent, reliance must be placed on the character of the excavation of the optic nerve, which in glaucoma, as already pointed out, covers the whole surface of the disk, has steep sides, and is deeper than the normal level of the lamina cribrosa. Physiological excavation involves only a portion of the disk, while the remainder of the surface presents a healthy appearance. The excavation due to atrophy of the nerve affects the entire disk surface, but it is shallow and slopes gradually to its deepest point. Moreover, the nerve-head is much more anemic, proportionately to the depth of the cup, than in glaucoma (consult Fig. 131). The greatest difficulty arises when an atrophic process attacks a nerve which is the seat of an extensive physiological pit. Flatness of the disk in the sound eye is evidence of glaucoma, since physiological cupping is bilateral (Schweigger).¹ The absence of the knee-reflex as indicative of central disease would point to atrophy.

The shape of the visual fields, especially the color-fields, and their relation to the acuity of vision are of decided, though not unqualified, diagnostic importance. In atrophy of the optic nerve good central vision and color appreciation are not so apt to be retained with a contracted field for form as in glaucoma. (Compare with page 448.) In doubtful cases the totality of the phenomena must be considered, and sometimes a positive diagnosis should be reserved and the course of the affection carefully watched.

The unfortunate mistake of regarding the gray or green reflex from the lens as indicating incipient cataract, and the consequent advice to wait for ripening which never comes, are happily much rarer now than they were before improved methods in medical teaching, including instruction in the use of the ophthalmoscope, were inaugurated.

Treatment.—Had v. Graefe done nothing else for ophthalmology, his discovery in 1856 of the curative power of iridectomy in glaucoma would alone have secured for him an imperishable fame. Other remedial measures operative and medicinal have been since devised, but they are almost universally considered to be of secondary importance.

In performing iridectomy² for glaucoma the coloboma should be made upward, so as to be covered by the upper lid, unless the superior portion of the iris appears to be specially atrophic, and therefore more difficult to remove. The incision should lie in scleral tissue, should be of ample size, and should be completed with deliberation in order to prevent too sudden a reduction in tension, which might be attended with intraocular hemorrhage, rupture of the zonula, or other disastrous consequences. The bit of iris excised should be extensive, and should embrace the whole width of this tissue up to its ciliary margin. The angles of the wound should be left entirely free, an iris-repositor being used if necessary.

¹ This statement of Schweigger's is not without exceptions, as a unilateral physiological cup may exist.—Ed.

² The operation for iridectomy is described on page 575.

The operation, which should of course be made with precautions against sepsis, requires in inflammatory cases the use of a general anesthetic, as cocaine under these circumstances is very imperfectly absorbed. Hemorrhage into the anterior chamber is not infrequent, but the blood usually undergoes absorption in a few days. Retinal hemorrhages are also occasionally seen. These are generally not extensive, and they soon disappear.

Cystoid cicatrix from imperfect apposition of the lips of the operation-wound is sometimes unavoidable. Moreover, though a blemish, it may serve to facilitate filtration.

The most brilliant results of iridectomy are obtained in acute inflammatory glaucoma, especially when the operation is done without delay. The pain, high tension, and corneal cloudiness promptly disappear, and the vision is rapidly and decidedly improved—sometimes, indeed, entirely restored.

In the chronic forms of the disease the operation, owing to the degeneration and excavation of the optic nerve, does not accomplish so much. In chronic inflammatory glaucoma, however, the morbid process is usually checked unless the iris-tissue has become degenerated (Gruening).

In simple glaucoma the experience of v. Graefe, Bull, Nettleship, Fuchs, and others shows that by means of iridectomy the existing vision is preserved or slightly improved in about half the cases. In some of the remaining half the influence of the operation is negative; in others it seems to expedite the morbid process; while in a small proportion—estimated by some authors at about 2 per cent.—the iridectomy is followed by pericorneal injection, steaminess of the cornea, and great increase in tension. The anterior chamber remains empty and vision is almost always destroyed. This condition, which is very rarely observed in the congestive types of the disease, has received the name of *malignant glaucoma*. The predisposition to it seems to affect both eyes. Hence the propriety of Schweigger's rule to operate on the worse eye first, even if it be blind. If this heals smoothly, the other may be expected to follow a similar course, but, as Friedenwald has shown, it may occur even where the operation on the first eye has healed without complication.

Absence of increased tension and a greatly restricted visual field diminish, although they by no means annihilate, the chances of benefit from iridectomy in simple glaucoma.

The *modus medendi* of iridectomy is not understood. The explanations so far attempted are merely of speculative interest.

Of the numerous operative procedures devised to substitute iridectomy in the treatment of primary glaucoma, the majority, including those of Hancock, Knies, Nicati, Pflüger, Vincentiis, Badal, and Parinaud, and the combined sclerotomy of De Wecker, serve chiefly to illustrate the ingenuity of their inventors. Iridectomy has only one serious rival—viz. *sclerotomy*, and this is by almost universal consent relegated to a subordinate place. Sclerotomy, the technique of which is described on page 569, ought to be performed when the symptoms persist after a well-executed iridectomy, and preferably opposite the latter. It may also be resorted to when the iris has undergone degenerative changes which would be likely to preclude a satisfactory excision of this tissue. If done in a case of simple glaucoma with a contractile pupil, eserine should be previously instilled in order to prevent prolapsus iridis. Priestley Smith and Harold Gifford strongly recommend scleral puncture 5 mm. behind the cornea as a preliminary step to iridectomy in cases where the anterior chamber is very shallow.

In cases of absolute glaucoma which are attended with great pain unre-

lieved by iridectomy, or in which this operation is impossible of performance, enucleation, or, according to some, optico-ciliary neurotomy, becomes necessary.

The *non-surgical treatment* of glaucoma consists principally in the instillation into the conjunctival sac of solutions of eserine or pilocarpin of moderate strength, gr. $\frac{1}{8}$ to $\frac{1}{2}$ to f $\overline{3}$ j, although much stronger solutions are frequently required. Myotics are most serviceable in the prodromal stage of inflammatory glaucoma, but they will often hold an acute attack in check, and thus permit of delay if circumstances prevent an immediate operation. They are useful in many cases of simple glaucoma, especially with increased tension, in which an operation is contraindicated or is rejected by the patient. It is known that iridectomy in a case of unilateral glaucoma is sometimes suddenly followed by the appearance of the disease in the normal eye. The use of eserine in the latter at the time of the operation is believed to be an efficient means of averting the danger. As regards the use of myotics, the general consensus of opinion is that they are rarely more than palliative in their action. They should not be employed too long, because, apart from the external irritation often produced by them, they tend to increase ciliary congestion, and they do not always retard the progress of the excavation in the optic nerve.

The efficacy of *massage of the eyeball*, recommended by Gould and other observers, has not yet been sufficiently tested. It might be useful in deepening a shallow anterior chamber previously to operating.

Constitutional remedies for glaucoma do not have much vogue, but the reports of Sutphen and Friedenwald indicate that sodium salicylate in large doses has decided therapeutic value.

Glaucomatous tendencies should be combated by the correction of refractive errors, by the avoidance of constipation and of over-indulgence in eating and drinking, by regular open-air exercise, and, above all, by the cultivation of self-control, since a glaucomatous attack so frequently means the explosion of emotional dynamite.

II. Secondary glaucoma is the name employed to describe a condition in which the more striking phenomena of glaucoma—increased tension, shallowness of the anterior chamber, etc.—are developed as consequences of some antecedent disease or injury.

The pathological conditions which most frequently give rise to secondary glaucoma are perforating wounds of the cornea, either accidental or surgical (*e. g.* hypopyon-operations), suddenly closed corneal fistulæ, corneal cicatrices, especially with staphyloma or incarceration of the iris, serous iritis and iridochoroiditis, occlusion of the pupil, traumatic cataract with swelling of the lens, dislocation of the lens, either forward against the cornea or backward into the vitreous, intraocular tumors, and contused wounds of the eyeball. The author has observed glaucoma follow a blow causing rupture of the choroid.

1. **Hemorrhagic glaucoma** is consecutive to retinal hemorrhage due to atheromatous or hyaline disease of the blood-vessels. It may appear with albuminuric retinitis. The intensity of the symptoms varies very much in different cases, as does also the time of their appearance after the discovery of the extravasations. It is difficult in many cases to decide whether the glaucoma is produced by the hemorrhage or the hemorrhage by the glaucoma. In severe cases hemorrhage into the vitreous entirely obliterates the fundus reflex.

2. **Complicated glaucoma** comprises those cases of the disease which

arise during the progress of some other affection, but in which the causative influence of the latter is doubtful. The most noteworthy of such complications are *cataract, atrophy of the optic nerve, pigmentary retinitis, and myopia* of high degree.

Treatment.—The treatment of the different forms of secondary glaucoma depends upon etiological considerations. A swollen or dislocated lens should be removed, an incarcerated iris set free, and an occluded pupil remedied by a generous iridectomy.

Hemorrhagic glaucoma responds badly to any form of treatment. Iridectomy is dangerous, being liable to be followed by increased retinal hemorrhage. Anterior sclerotomy or eserine may prove of service. In some cases posterior sclerotomy has been found beneficial. General treatment should not be neglected—ergot, cautious use of cardiac sedatives, the alteratives, and strict regulation of diet and mode of life.

III. Buphthalmos.—*Kerato-globus, Congenital Hydrophthalmos (Glaucoma Congenitum).*—This is a form of glaucoma pertaining to childhood, and characterized not only by elevated tension and cupping of the optic disk, but also by enlargement of the globe. The cornea, which may be either clear or opaque, is usually very thin and its diameter greatly increased. The anterior chamber is deep, the pupil dilated, and the iris tremulous from stretching or rupture of the zonula. The lens remains small. The pathology is obscure, but the condition is supposed to be due to an inflammation of the uveal tract dating back to intra-uterine life and causing an obstruction to excretion. The distention of the eyeball is explained by the fact that the sclera of the child is more yielding than that of the adult.

Treatment.—Iridectomy is contraindicated. Stölting reports favorable results from repeated sclerotomies, and Snellen from frequent puncturing of the anterior chamber. Eserine and pilocarpin should be tried. The prognosis is very unfavorable.

DISEASES OF THE CRYSTALLINE LENS.

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Cataract.—The general term “cataract” is accepted in modern medicine as meaning any opacity of the crystalline lens. A capsular opacity is denominated a *capsular cataract*, and an opacity involving both capsule and lens substance a *capsulo-lenticular cataract*.

History.—While cataract was well known to the ancient Greek and Roman physicians, our knowledge of its true nature dates from the beginning of the last century. Even before this one or two savants, as Mariotte and Boerhaave, recognized the real situation of the opacity, but their doctrines failed to obtain general acceptance. In the year 1705, Brisseau, a French surgeon, had the opportunity of making an autopsy upon the body of a soldier who had a mature cataract. Brisseau performed depression of the cataract upon the cadaver and then opened the eye, when he found that the opacity which he had depressed into the vitreous was the lens. He laid his observations, together with the conclusions drawn from them, before the French Academy, but they obtained no credence. The Academy confuted him by holding up the doctrines of Galen in regard to cataract. It was not till three years later, when new proofs had been brought forward, that the Academy recognized the new doctrine, which soon found general acceptance.

Varieties of Cataract.—Cataract may be *primary*, or *secondary* to some ocular disorder, or it may be *symptomatic* of systemic disease or local injury.

It may be *progressive* or *stationary*, *partial* or *complete*, and in color *black*, *white*, or *amber*.

Various classifications of cataract have been adopted by different authorities, the simplest divisions being into the soft, hard, secondary, and irregular and special forms, with their subdivisions:

Soft,	{	Congenital or Juvenile, Complicated or Traumatic.	{	Complete, Partial,	{	Lamellar, or zonular. Pyramidal, or polar.
Hard,		Senile,	{	Cortical. Nuclear.		
Secondary,	{	Anterior Polar Cataract. Posterior Polar Cataract. After-cataract.				
Irregular and		Special Clinical Forms.				

I. Congenital or Juvenile Cataract.—While the congenital or juvenile cataract is the commonest form of the soft variety, developing idiopathically, its complete variety is not frequently encountered, De Wecker having noted but 36 in 40,000 cases of ocular disease.

(a) **Lamellar or Zonular Cataract.**—This is the most frequent variety of congenital opacity of the lens. The opacity exists only in certain layers of the lens, between which are perfectly clear spaces. It is distinctly seen with oblique illumination, the opacities appearing of a light-gray color with translucent interspaces. When partial, little beyond a gray blur can be detected by close examination. Through the dilated pupil the ophthalmoscope will reveal, however, a sharply-cut, well-defined opacity, surrounded by a reddish circle due to reflection from the fundus.

Constitutional conditions are important factors in the development of this variety of cataract, rachitis, hereditary syphilis, or scrofula often being associated with it. There may be imperfect cerebral development, and Arlt found in 29 such cases that 25 were affected with convulsions. Dental defects are common, the incisors and canines being marked with transverse lines, furrows, or terraces. Usually lamellar cataract is *double*, but it may be *monolateral*, and is either congenital or forms in early infancy. The former variety may be ascribed to developmental defects; the latter, to disturbances of nutrition dependent upon the causes just enumerated.

Congenital cataract may be found with other abnormal ocular states, coloboma, microphthalmos, irido-choroiditis, and choroido-retinitis being the most common. Disturbances of nutrition during intra-uterine life, arrest of development, and the influence of heredity are factors in the production of congenital cataract. In forms of cataract developing during early life the influence of heredity is strong, and notable examples of the affection appearing in many members of the same family are on record.

(b) **Complete Cataract of Young Persons.**—This is a soft cataract of milky or bluish-white color. It has no yellow reflex; it belongs to youthful life and rarely occurs after thirty-five years, before which period the lens is "soft"—i. e. the nucleus is small. It may degenerate and become fluid, or cholesterin crystals or chalky deposits may be found in it. It may arise without known cause, and often is monolateral.

II. Traumatic Cataract.—This may develop from direct laceration of the capsule and lens-fibers, and the rapidity of its progress is dependent upon the amount of surface exposed by the torn capsule. A normal lens, freshly removed and placed in water, very soon will absorb abundant fluid, and in the process of doing so will swell and become opaque and disorganized. This is exactly what takes place when the capsule is wounded. If the anterior capsule is opened, the aqueous is absorbed; if the posterior capsule, the vitreous.

Within a few hours after the accident the lens in the vicinity of the injury becomes slightly puffed and cloudy. Soon this soft, pulpy mass forces itself through the capsular wound and protrudes into the anterior chamber. It may be absorbed, but in the mean time mass after mass of the swollen fibers follows and the entire lens becomes opaque and gradually disappears. Hence in favorable cases a clear, black pupil with good vision may be the result. In unfavorable cases some inflammatory complication arises—iritis or cyclitis—and if there is any infection through the corneal wound, a purulent process may develop which will probably destroy the eye. At best, adhesions result which may lead to detachment of the retina or increase of tension. A lens which swells very quickly may produce a pressure-inflammation.

Cataract may develop from an indirect injury, without apparent rupture of the capsule, such as a blow on the head or side of the face, or as the result of an explosion, and it is then termed "*concussion cataract*." In these cases there is a slight rupture of either posterior or anterior capsule. Occasionally, after both direct or indirect trauma of the lens, the opacity is limited and remains stationary.

III. Complicated Cataract.—This may develop as the result of pathological changes in almost any of the tissues of the eye. It is commonly associated with iritic adhesions, cyclitis, irido-choroiditis, glaucoma, opacity of the vitreous, and detachment of the retina. The *prognosis* of complicated cataract is far less certain than in ordinary cases, and operation more difficult. Indeed, operative treatment is frequently contraindicated, or some special method of surgical procedure must be devised to meet the indications.

IV. Senile Cataract.—Hard (because the nucleus is large), simple, gray, or senile cataract, as it is variously designated, develops after middle life, most commonly after forty-five years.

The rate of development varies greatly. Sometimes the cataract will

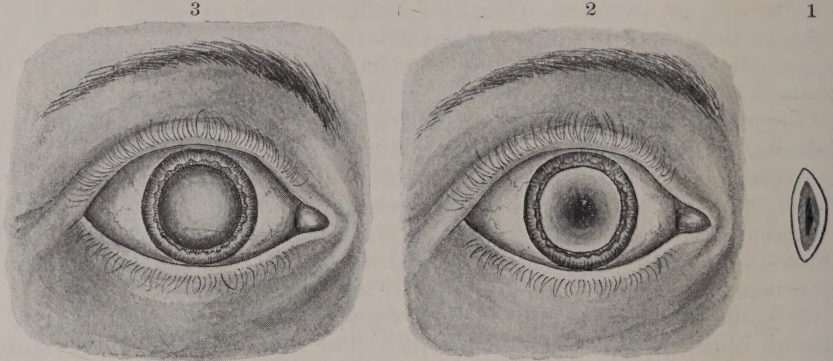


FIG. 250.—Nuclear cataract: 1, section of lens, central position of opacity; 2, appearance by transmitted light; 3, appearance by oblique illumination. (Modified from Nettleship.)

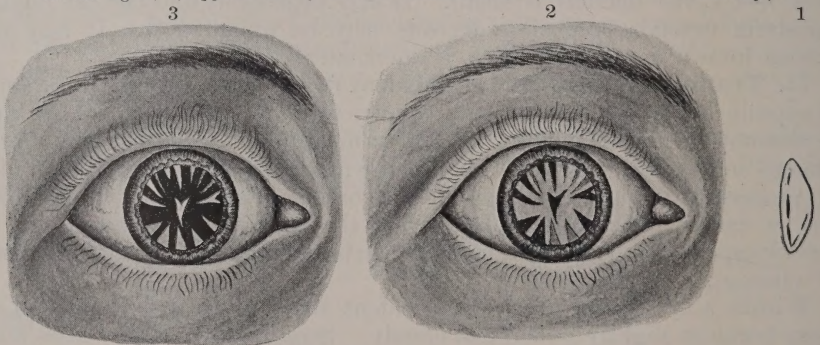


FIG. 251.—Cortical cataract: 1, section of lens, opacities beneath the capsule; 2, opacities seen by transmitted light (ophthalmoscope mirror); 3, opacities seen by reflected light (oblique illumination). (Modified from Nettleship.)

remain stationary for years; again, it will ripen completely in a few months. It may progress rapidly for a time, then remain stationary for years, and finally resume its rapid progress. It nearly always affects both eyes, but usually one considerably in advance of the other.

Almost from birth there is greater density in the deeper or more central layers of the lens than in the superficial. This is not appreciable until after

the age of thirty-five. Then close examination will discover that the lens consists of a dense, hard, more opaque, central part, the *nucleus*, and a softer and more transparent surrounding mass, the *cortex*.

This physiological condition may continue indefinitely, with perfect vision, or the central part may become denser, more deeply stained and opaque, and form a *nuclear cataract* (Fig. 250). But pure nuclear cataract is rarely found. The cortex almost invariably is involved in the cataractous process (*cortical cataract*) (Fig. 251), but the conditions of hard interior and softer surface continue in greater or less degree in all cases.

The commencement of a senile cataract is somewhat variable. It may first appear in dark, linear striations passing from the margin to the center of the lens, or it may proceed from the anterior to the posterior surface. There may be stellate opacity or irregular and unequal dotted spaces. The cataract may commence at the *equator* or edge of the lens, or *centrally* at the nucleus. In some cases these linear striations remain stationary for many years. While evidently indicating beginning cataract, they have received the name of "gerontoxon lentis" or "arcus senilis lentis."

V. Secondary Cataract.—This includes three chief varieties:

(a) **Anterior polar or pyramidal cataract** results from a central perforating ulcer of the cornea (Fig. 252). It may appear as a conical mass projecting

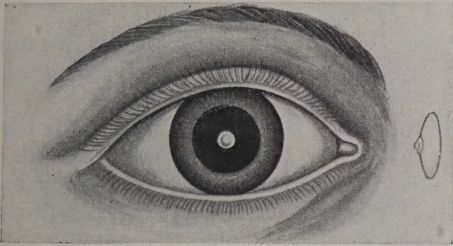


FIG. 252.—Anterior polar cataract (after Nettleship).

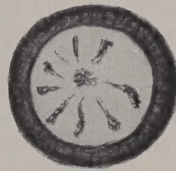


FIG. 253.—Posterior polar cataract seen by transmitted light (from a case of pigmentary degeneration of the retina).

forward from the surface of the lens, attached to the margin of the ulcer, or having a thread-like connection with it, or as a small white dot on the capsular surface. This condition is extremely unsatisfactory in regard to treatment, and its effect on vision is most serious.

(b) **Posterior polar or pyramidal cataract** is dependent on choroidal disease, especially disseminated choroiditis. It is found as a star-shaped opacity associated with high myopia, and often with extensive opacities in the vitreous, and less frequently with pigmentary degeneration of the retina (Fig. 253). It is also caused by the vestigial remains of the hyaloid artery at its lenticular attachment. Small posterior capsular opacities from this source are common and do not disturb vision. Among 1884 patients examined by Mittendorf, 44 were thus affected. In the course of posterior polar cataract the lens itself will often become opaque, the opacity manifesting itself as a general cloudiness or as innumerable dots scattered throughout the lenticular tissue.

(c) **After-cataract** (also called *secondary cataract*) is the condition usually left after the operation of extraction of cataract. The changes occur in the capsule; the opening may be closed by a delicate veil; the capsule-cells may proliferate, resulting in increased thickening; or there may be a plastic deposit, leading to occlusion of the pupil.

VI. Capsular Cataract.—This name is applied to any thickening or hyperplasia of the capsular epithelium, which resembles connective tissue. It may be congenital or result from ulcerative processes in the cornea, either with or without perforation of the cornea. According to Mules, cretified remains of the pupillary membrane explain some cases.

VII. Capsulo-lenticular Cataract.—Not only is there lenticular change in this variety, but there is hyperplasia of the cells on the posterior surface of the anterior capsule, causing thickening of that membrane, commonly in its center.

VIII. Special Clinical Forms of Cataract.—*a. Diabetic Cataract.*—This is usually of the *soft* variety, is rapid in its formation, and almost invariably affects both eyes. If it develops in elderly persons, it may be more consistent and have a more or less firm nucleus. It is often accompanied by lesions of the deeper tissues of the eye, as retinitis or optic neuritis. If possible, prior to operation these facts should be carefully ascertained on account of their bearing on the prognosis.

b. Albuminuric Cataract.—Although changes in the lens are sometimes found in association with Bright's disease, they are infrequent, and no direct connection between the two can be traced. It is well known that, as a rule, cases of cataract attributed to albuminuria make good recoveries after operation, and a fair degree of vision is secured. Other uncommon forms of cataract are—

c. Central lental cataract, which consists of a white opacity in the center of the lens, due probably to faulty development at an early stage of intra-uterine existence.

d. Punctate cataract, in which the opacities present themselves in the form of fine points and dots, either occupying the center of the lens or distributed throughout its substance. Punctate cataract may be congenital or develop in later life. Usually it remains stationary for a long time, but occasionally progresses to maturity.

e. Fusiform cataract, which is characterized by an opaque stripe passing from the anterior to the posterior pole of the lens.

Pathology and Pathological Anatomy of Cataract.—While the exact process which produces cataracts is still obscure, the development of opacity of the crystalline lens, most frequently associated with old age, is undoubtedly dependent upon some error of nutrition or upon some nutritive change secondary to disease in the deeper-seated tissues of the eye. This is evident from its frequent origin in some inflammatory disease in the iris, choroid, ciliary body, or vitreous humor. Any process which interrupts or diminishes the vascular supply to the anterior region of the globe, or interferes with the osmotic action of the nutritive fluids, will directly affect the normal conditions of healthful stability.

This interruption of natural conditions leads to slow but progressive changes in the lens-fibers. There is primarily a slight contraction, followed by increase in volume, owing to the imbibition of fluids; cholesterin is increased in amount, and the albuminoids diminished. The new cell-production from the intracapsular cells can be plainly seen with the microscope. Later, the lens-fibers atrophy, their volume diminishes, and irregular interspaces are formed, within which large amounts of fluid accumulate (Morgagni's globules). Often the fibers show punctate cloudiness, transverse striations, molecular degeneration, fat-globules, and cholesterin (Fig. 254).

Förster states that in the process of transformation of the inner layers of the lens into a nucleus the layers diminish in volume. Normally, this

process is so slow and gradual that the cortical layers adapt themselves to the contracting nucleus. If, however, the shrinking progresses rapidly or irregularly, there is extreme pulling or traction, with consequent separation of the layers which lie between the nucleus and cortex. In this condition fine fissures are formed and fluid accumulates in them; the adjacent lens-fibers become opaque and form the initial impulse which leads to complete lenticular opacity.

Etiology.—Cataract may be considered a disease of old age. While complete cataract is found at almost any period of life, it is comparatively rare before the fiftieth year.

Sex does not influence the development of cataract, except in the zonular variety, in which greater liability of females has been recorded. *Occupation* has but little influence on the development of the disease, although it has been observed to occur more frequently in those who are constantly subjected to intense heat, as laborers in Turkish bath-houses, glass-blowing factories, smelting-foundries, etc. *Heredity* has an undoubted influence.

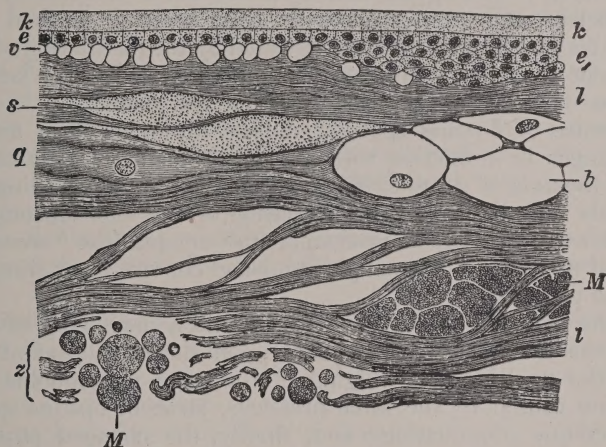


FIG. 254.—Cataracta capsulo-lenticularis, $\times 170$: *k*, anterior capsule of the lens; *e*, epithelium, occurring at *e*, in several layers because of proliferation; *l*, normal lens-fibers; *v*, light-colored vacuoles (drops of liquor Morgagni) between *l* and the epithelium. The fissures originating through the separation of the lens-fibers are filled with a granular mass (coagulated fluid), *s*, which in places forms the spherules of Morgagni, *M*. The lens-fibers themselves are swollen up (*q*), or transformed into vesicular cells (*b*), or entirely disintegrated (*z*) (Fuchs).

There are examples where many members of the same family are afflicted. The author has met with cataract in the four children of one family, both father and mother having developed the disease at an early age. Hasket Derby has recorded 8 cases of rudimentary double cataract among 10 members of the same family, and John Green 21 cases of cataract among 71 persons belonging to 6 successive generations of one family.

Both *acute and chronic diseases of the eye*—iritis, irido-choroiditis, iridocyclitis, glaucoma, diseases of the vitreous, and most commonly extensive and long-standing detachment of the retina—frequently cause cataract. It is especially apt to develop after purulent processes, such as hypopyon-keratitis or purulent choroiditis.

Such diseases as idiopathic fever, typhoid fever, diabetes, albuminuria, atheroma of the carotid, gout, syphilis, influenza, rachitis, bronchocele, meningial inflammation, and convulsive seizures have been associated with cataract formation. It has been attributed to pregnancy and prolonged lactation.

In epidemics of *ergotism* cataracts are frequently found (*raphanic cataract*), and artificial cataract may be induced in animals by feeding them with naphthalin (*naphthalin cataract*). For that form of cataract found in diseases of the uveal tract and in anemia and marasmus the name "starvation cataract" has been suggested.

The influence of *accommodative strain* on the production of cataract, as well as other serious ocular disturbances, is not thoroughly understood. A large proportion of cataractous eyes are ametropic. It is probable that the constant effort of the ciliary muscle unfavorably influences the nutritive processes of the lens.

The influence of *traumatism* in the production of cataract has been described. Some cases have followed a lightning stroke, but have also been associated with optic neuritis, rupture of the choroid, iritis, or irido-cyclitis.

Symptoms.—During the development of cataract, especially the senile form, the chief *subjective symptom* is a gradual but steady loss of vision. In those cases where the periphery of the lens is first affected very extensive opacity may form without great loss of vision; but if the opacity invades the center or nucleus, the interference with sight becomes marked at an early stage. This may be beautifully demonstrated by the instillation of a mydriatic—improvement in vision will at once appear. It is in this latter class of cases that an iridectomy may prolong vision for years.

The presence of floating spots or muscæ, diplopia, often monocular, or polyopia, changes in refraction with the development of astigmatism, or the alteration of the axis of a pre-existing astigmatism, are exceedingly common, and are mainly due to the irregular swelling of the lens-substance. This is so great at times as actually to produce a true myopia (the "*second sight*" of the aged), and necessitates a greatly diminished convex, or at times a concave, glass (see also page 222).

Among the *objective symptoms* will be found a narrowing of the anterior chamber in the early stages, consequent upon the advancement of the iris and due to the swelling and bulging of the lens; photophobia, due to the iritic irritation caused by the same pressure; striæ or opaque spots, demonstrable by oblique illumination; and, finally, the changed pupil, which is altered from a brilliant black to a staring yellow, white, or brown. Sometimes the lens becomes so deeply stained as to appear dark brown or black (*cataracta nigra*); sometimes it is of a milky, bluish-white color; and sometimes the cortex degenerates, becomes fluid, and the hardened nucleus sinks to the bottom of the shrivelled capsule (*Morgagnian* or *overripe cataract*).

For clinical study Fuchs divides the periods of the development of a progressive cataract into four stages, as follows:

1. *Stage of Incipieny (Cataracta Incipiens).*—In this stage opacities are found throughout the lens, usually in the shape of sectors or spokes, with spots still transparent. The anterior chamber is of normal depth.

2. *Stage of Swelling (Cataracta Intumescens).*—The lens has now absorbed more fluid, swelled up, and has pushed the iris forward and reduced the depth of the anterior chamber. The opacity becomes total in this stage. The lens is bluish-white and has a silky luster. The markings of the stellate figures are very distinct.

3. *Stage of Maturity (Cataracta Matura).*—Contraction has now taken place, and most of the fluid absorbed has been lost. The anterior chamber has resumed its normal depth, and the lens, losing its brilliant, iridescent look, has a dull-gray or brownish appearance.

4. *Stage of Hypermaturity (Cataracta Hypermatura).*—If the change

continues, the cortex undergoes disintegration and becomes either a soft, pulsatous mass without structural elements, or, if the fluid is absorbed, a dry, inspissated, flattened, cake-like body. The anterior chamber is normal, and the surface of the lens is homogeneous, or reveals irregular dots instead of the usual radial markings.

Diagnosis.—The old *catoptric test* may still be used to detect the presence of cataract, as well as to determine the presence of the lens or of a black cataract. In a darkened room a lighted candle is moved before an eye with properly dilated pupil. If two erect images and one inverted image are reflected respectively from the anterior surface of the cornea and the anterior and posterior surfaces of the lens, the lens is intact. If, however, the posterior inverted image is absent, there is some opacity behind the anterior capsule, and if the deeper erect image is wanting, the opacity involves the anterior capsule.

With *oblique illumination* the opacities appearing as gray spots or striations may be easily recognized. The use of the *ophthalmoscope* has caused all other methods to be abandoned. It has rendered the detection of cataract a matter of immediate and certain demonstration. The patient, with pupil dilated with cocain or homatropin, is taken to a darkened room and placed in the position for ordinary ophthalmoscopic examination. Light is reflected from the mirror through the enlarged pupil, and the interruptions to the normal reflex from the choroid will indicate the lenticular opacities, which appear as black spots or as lines or streaks radiating from the margin to the center. The nucleus may be hazy, or the center may appear clear with opaque rings surrounding it. The sectors of the lens may be denser than normal, or lenticular flaws, resembling cracks in glass, may be seen. Finally, there may be entire absence of the reflex due to complete opacity of the lens body.

The Process of Ripening.—The *course* and *development* of cataract vary greatly. In the simple or senile form the time from incipency to ripeness may vary from a few months to many years; the usual time is from one to four years. Cortical cataract may remain immature for a prolonged period (fifteen to twenty years); hence the wisdom of a guarded prognosis. Finally, when the entire substance of the lens has become opaque, when the swelling has subsided, and the anterior chamber has resumed its normal depth, the cataract is *ripe*. This period may be determined by illuminating the pupil and carefully observing if the shadow of the margin of the iris is reflected from the lens. In case no shadow is seen the cataract is complete and ripe; if the shadow is present, there is still a transparent reflecting layer of the lens beneath the capsule (Fig. 255).

A mature cataract has the property of separating readily from its connection with its capsule. As suggested by Arlt, it lies in its capsule like a ripe fruit in its rind. The cause of this will probably be found in the preliminary swelling and contracting of the lens-substance, and the consequent loosening of the surface from the capsule.

Prognosis.—This should be guarded in immature cataracts of all varieties, but especially in the linear cortical variety, with which good vision may be retained for a period varying from fifteen to twenty-five years. The following considerations should influence the prognosis with reference to the

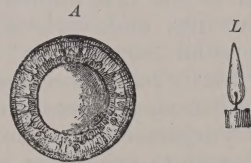


FIG. 255.—Shadow of the iris seen from the front, appearing on that side of the iris which is toward the light, L (Fuchs).

result of operative procedure: The want of health in surrounding tissues; disease of the nasal or lachrymal passages; various forms of inflammation of the conjunctiva and margins of the lids; the size and consistence of the nucleus; the degree of maturity of the cataract; the general condition of the patient and the presence of general disease, such as diabetes, chronic nephritis, or bronchitis, with constant cough; the presence of extreme myopia or hyperopia; immobility or tremulousness of the iris; and contraction of the light-field, or want of light-perception due to serious ocular disease, such as glaucoma or retinal detachment. The presence of diabetes or Bright's disease, while complicating, does not contraindicate operation. Extreme age does not necessarily complicate the result.

The *light-field*, upon which the final prognosis is based, providing other complicating circumstances enumerated are absent, is thus tested: Place the patient before a lighted candle about four meters distant; the flames should be distinctly recognized. This gives evidence that the macular region is probably free from coarse disease. Now cause the eye under examination to fix the flame attentively, and move a second lighted candle radially through the field of vision. The flame should be recognized as soon as the rays strike the edge of the cornea, and the patient should be able to indicate the direction in which the light is coming. Thus the "light-field," or the "projection of light," is tested, and, if the answers have been accurate, "projection of light is good in all parts of the field."

Even after complete absorption of congenital cataract under the influence of repeated discissions, useful vision is not always restored, because of associated optic nerve-atrophy, choroidal disease, or changes at the macula. The functional condition of an eye with total congenital cataract is usually less favorable than one with the zonular variety of the disease.

Treatment.—From the earliest period ophthalmologists have eagerly sought some method of absorbing or dissipating the cataractous lens. Various suggestions have been made, and various methods of procedure, such as *massage* and passing the *electric current*, have been tried, but with negative results. So long as glasses, changed in accordance with the altering refraction of the eye, improve vision, they may be worn. Tonics are useful as adjuvants, and various alteratives—*e. g.* iodid of potassium—to relieve choroidal congestions may be exhibited. During incipency moderate mydriasis may assist vision. At the proper time, however, surgical interference becomes necessary.

Various important questions arise in determining the best course to be followed to bring the treatment of cataract to a happy conclusion. When should extraction be made? Are we justified in hastening the process of ripening, and should we interfere when one eye is intact and has normal vision?

1. Extraction of Immature Cataract.—Most ophthalmic surgeons delay extraction until the process of ripening is complete. While this is, perhaps, the wisest plan, everything considered, it is by no means the only one. The danger of an early operation—the swelling of the softened unripe cortex—can be largely overcome by washing out the cavity with warm saline solutions, after the method of Panas and other operators, subsequent to extracting the nucleus.¹ About the sixtieth year of life, and even earlier, an unripe cataract may be successfully extracted.

¹ Irrigation of the anterior chamber, in the opinion of the editor, is an unwise procedure. If the capsule is properly opened (see page 581), the danger of swelling of cortical remnants is small—smaller than that which follows irrigation.

2. **Artificial ripening of cataract** is rarely justifiable. It subjects the patient to a second major operation on the eye, with the attendant dangers. When this operation is determined upon it may be performed according to one of the methods described on page 584.

3. **Extraction of Monocular Cataract.**—Unless the cataract is hypermature or a cosmetic effect is greatly desired, we are hardly justified in extracting an opaque lens when the other eye has normal vision. The advantages of a successful operation are that the field of vision of the affected side becomes more extensive, and the patient possesses an eye ready for use should vision in the other eye become involved from any cause. On the other hand, while binocular vision is possible, objects are constantly blurred and sharpness of contour is wanting. The operated eye sometimes lags behind the other, giving an awkwardness of expression more grotesque and less pleasing than the presence of the cataract.

4. **Operations for Cataract.**—For soft cataracts *discission*, the *method of suction*, a combination of these methods, or *linear incision* may be practised. The use of the needle, repeated if necessary, will suffice in the usual soft varieties, while the suction method will quickly extract the contents when of semifluid consistency. It is not wise to delay the removal of a congenital cataract beyond the early weeks of life, as interference with the development of the retina and other deeper tissues of the eye may result.

Partial congenital cataracts are treated by *optical iridectomy* or *discission*. The former method is applicable to those cases whose vision is improved by dilating the pupil.

Discission is practised for the after-cataract, not to produce absorption, but to open a passage for the light-rays (see page 585).

For the removal of the hard or senile cataract one of the various *methods of extraction* should be followed. The results of this operation are such that the older method of *couching* has been completely abandoned. While the exact technique of the various operations will be found elsewhere (see chapter on Operations, p. 580), several important points may be properly referred to here. The corneal incision should be ample in size, and should be completed with as few motions as possible, the subsequent rapid union of the cut surfaces being somewhat dependent upon this. The question of an iridectomy is much discussed, each individual operator having finally to determine the method from his own experience. Probably simple extraction (without iridectomy) is now performed in 60 per cent. of the cases, the maturity of the cataract, the condition of the iris, and the question of drainage determining the method. A wise rule is to perform simple extraction, examine the eye within twenty-four hours, and, if the conditions are not favorable, separate the lips of the wound and resect the iris. The extrusion of the vitreous during the operation is usually due to insufficient rupture of the capsule and excessive pressure in delivering the lens. Unless it is so great as to cause total collapse of the globe the removal of the lens may be successfully attempted by other means. A degenerated or fluid vitreous may instantly force the operator to desist.

Aphakia.—In the normal eye the removal of the lens (aphakia) causes a high degree of hyperopia, about 11 D. In myopia the degree of hyperopia will be lessened, and, indeed, in myopes of high degree emmetropia may result from extraction of the lens, or, if the myopia has been very great, a portion will remain unneutralized by the artificial hyperopia. In addition to the hyperopic refraction which results from cataract extraction, regular astigmatism is often found. It is probably produced by the irreg-

ular contraction of the cicatrix, and is usually "contrary to" or "against the rule." It is always greatest in the early months after the operation, and slowly diminishes. These conditions can be much relieved by the application of suitable glasses. In the average case a simple sphere of from 8 D. to 12 D., with the addition of a cylindrical glass of from 2 D. to 3 D., axis contrary to the rule, will usually suffice for good distant vision. For reading an additional sphere of from 4 to 6 D. must be added.

Perfect vision—*i. e.* $\frac{6}{6}$ —is often secured after extraction, but $\frac{1}{6}$ or even $\frac{1}{10}$ of normal vision is sufficient to place the case within the list of successes. Frequently the vision can be materially improved by splitting the capsule. Glasses should not be adjusted until all signs of irritation have subsided.

Changes of Position of the Crystalline Lens.—The various changes which the position of the crystalline lens may assume, termed *luxation* and *subluxation*, may be congenital or acquired. The lens is supported firmly in its natural position by the zonula of Zinn or the suspensory ligament, and displacement of the lens is only possible by relaxation or elongation of the zonula fibers or by their destruction.

1. *Congenital dislocation*, or *ectopia lentis*, is almost invariably a subluxation, and is due to the unequal length of the zonula in various directions. The zonula being shortest above, the lens will be found displaced upward or upward and outward. Later in life the displacement may become complete. Both eyes are usually affected, but monocular cases are reported. Heredity appears to exert a marked influence on the production of congenital dislocation.

2. *Acquired dislocations* are the result of injury, usually a concussion which forces the aqueous backward and ruptures the delicate membrane of the zonula. The displacement may be complete or incomplete, the lens being forced forward into the anterior chamber or backward into the vitreous, or through a laceration of the external coverings of the eye beneath the conjunctiva, and even under Tenon's capsule. Occasionally it is completely expelled (see also page 366).

Symptoms.—In *subluxation* the anterior chamber is found of unequal depth, the iris being pushed forward at one point by the margin of the lens. The iris, losing its support in part, is no longer stationary, but trembles with every motion of the eye. With the ophthalmoscope the edge of the lens is seen as a dark grayish line. There may be loss of accommodation and monocular diplopia. In *complete luxation forward* the lens will be easily recognized by its shape as it rests in the anterior chamber or bulges out beneath the conjunctiva. In *posterior dislocation* the conditions simulating extraction are present. With every form of luxation very considerable changes in vision are noticed. In subluxation myopia may be present, and a considerable degree of astigmatism. In complete dislocation backward the extreme hyperopia of the aphakic eye is produced. The lens almost invariably undergoes cataractous changes, and by pressure may produce very serious inflammatory changes in the other tissues of the eye—iritis, cyclitis, and choroiditis—or by closing the angle of the anterior chamber, giving rise to glaucoma (see also page 366).

Treatment.—In partial dislocations the vision should be improved as much as possible by appropriate glasses. In complete anterior dislocation the lens should be removed through a proper incision. Where the dislocation is backward, unless there is some irritation, no attempt at removal should be made. When there is danger to the eye an effort should be made to press the lens forward into the pupil space by passing a needle through the

sclera behind the lens, and then extracting it through a corneal wound (see also page 582).

Congenital Anomalies.—Congenital cataract and congenital ectopia lentis have been recorded. In addition, there remain to be described—

1. *Congenital Aphakia.*—Total absence of the lens at birth is a condition of which there is no recorded example. Total absence of the lens has been found, however, in rare instances, as the result of some intra-uterine disease.

2. *Coloboma of the Lens.*—Coloboma of the lens almost invariably accompanies a similar condition of the iris or choroid, especially the former. The evenly rounded margin of the lens is replaced by a straight border or, it may be, by a notch of greater or lesser depth. Heyl states that the coloboma is almost invariably found in the lower segment of the lens. It may considerably disturb the visual acuteness.

3. *Lenticonus.*—This rare anomaly consists of a conical projection from the surface of the lens, usually from the *posterior surface*, or it may simply be an exaggerated curvature of the lens. On examination with the ophthalmoscope it resembles a drop of oil resting on the surface. It may or may not be associated with lenticular opacity. *Anterior lenticonus* also occurs.

DISEASES OF THE VITREOUS.

BY FLEMMING CARROW, M. D.,

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Hyalitis (*Inflammation of the Vitreous*).—This disease appears in two forms—one characterized by *suppuration* (*suppurative hyalitis*), and the other by either *fixed* or *floating opacities*.

Etiology.—All opacities seen in the vitreous, however, are not to be regarded as the result of pathologic conditions peculiar to that body, for they are usually dependent upon some structural change in the uveal tract or retina. On account of the absence of blood-vessels and nerves in its structure the vitreous was at one time supposed to be incapable of inflammation, but recent investigation has developed the fact that *idiopathic* or *spontaneous inflammation* may occur without change of a textural character in any other part of the eye. It is true, however, that hyalitis of the suppurative variety is generally a secondary disease, being caused by an injury (penetrating wound) to some adjacent structure, or by previously existing choroidal disease which had its origin, primarily, in consequence of some operative procedure upon some other part of the eye (as after cataract extraction).

Suppurative hyalitis may also be due to microbic invasion of old operative scars of several years' standing, to exhaustion following any lengthy debilitating disease, especially the continued fevers, relapsing fevers, the exanthemata, or may result from metastatic choroiditis after inflammation of the umbilical cord in new-born children.

Symptoms.—Since suppurative hyalitis is usually secondary to disease of other structures, we will find evidences of the presence of this primary affection in adhesions of the pupillary margin to the anterior capsule of the lens, and a history of iritis and cyclitis. Pus once having formed in the vitreous (the cornea and media being clear), it is readily seen with the ophthalmoscope occupying a circumscribed area (*pseudo-glioma*), while the rest of the vitreous may appear perfectly clear and healthy. This condition closely resembles a true glioma of the retina; but the history of the case, with the symptoms of iritis and diminished tension, will serve to distinguish them (see also page 356).

The disease may remain confined to some peripheral portion of the vitreous body, but usually the suppurative process extends until the entire vitreous becomes involved, and through a resulting *panophthalmitis* the eye is lost. The history of some pre-existing eye-disease and the ophthalmoscopic appearances will sufficiently indicate the location and gravity of the affection.

Prognosis and Treatment.—The result of suppurative inflammation of the vitreous is usually not only the loss of the affected eye, but the atrophied globe after panophthalmitis may be a source of menace to the sound eye. Should the health of the sound eye be threatened at any stage of the disease, enucleation of the affected organ must be at once performed.

During the course of any lengthy debilitating disease, should suppurative hyalitis supervene, it may be possible to save the eye with some degree of vision by vigorous tonic treatment. Intraocular injections of chlorin-water have been recommended on experimental grounds (Berry).¹

Opacities of the Vitreous.—That variety of inflammation of the vitreous characterized by the formation of *fixed* or *movable* opacities may be either *acute* or *chronic*.

Etiology.—As this form of vitreous disease, like the suppurative variety, is secondary to affections of other portions of the eye, the refraction of the eye and the condition of the lens, of the ciliary body, choroid, and retina, must be examined for its cause. High degrees of myopia associated with posterior staphyloma constitute a frequent cause of this trouble. Again, in choroiditis, and especially in the specific variety, a fine dust-like mist (*hyalitis punctata*) can be detected, through which there are distributed larger flake-like opacities of irregular shape, which give individuality to the primary disease which caused them.

Exhaustion of the general system from long-continued fevers, gout, constipation, anemia, interference with the function of the liver by congestion, irregular menstruation, syphilis, and the action of drugs (arsenic), all may, and often do, produce opacities in the vitreous. Injuries to the eye causing *choroidal hemorrhage* will also result in the formation of opacities, and, if extensive, may lead to suppuration.

Benson has described a form of opacity in which the vitreous is filled with minute, light-colored spheres (*asteroid hyalitis*). The condition is congenital, and does not interfere with normal visual acuity.

From the foregoing statements it is evident that opacities in the vitreous are generally the result of some pre-existing disease of some other part of the eye, although there may be a primary inflammation of this body to which they owe their origin.

Symptoms.—Patients readily see opacities of the vitreous, either as *fixed* or *movable* black spots, and are quite able to describe their situation, size, and shape. There may be no diminution of vision, although central vision may be entirely lost if there is a large centrally situated fixed opacity. Should there be pain or evidences of external inflammation, it must be taken for granted that the vitreal disease is complicated by some other affection, and probably the result of it.

The ophthalmoscope offers the one certain method of making a positive diagnosis if the media are clear. The patient is directed to move his eye quickly in all directions, and then to hold it quite still. The floating opacities are then seen to move in the vitreous, and gradually to sink to the lower portion of the chamber. Not only can the size of the opacities be correctly estimated in this manner, but a very good idea of the degree of fluidity of the vitreous can be obtained. It will be noticed, when the interior of the eye is illuminated by reflected light and the patient directed to move his eye, that these opacities move in a direction opposite to the movement of the eye: when the eye is turned to the right, the opacities move toward the left, and in this way they can be distinguished from opacities in the lens or cornea, which, being fixed, move with the movements of the eye. Fixed opacities in the vitreous may be discovered by using a strong convex lens (+ 16)

¹ The editor has also found that in experimentally induced suppurative hyalitis in dogs intravitreal injections of chlorin-water seemed to check the process, but is in entire accord with the author that intraocular injections are measures ordinarily to be condemned (see page 400).

behind the ophthalmoscope, the observer holding his eye quite close to that of the patient (see also pp. 178, 179, 183).

Treatment.—While treatment is not generally effective in entirely removing opacities of the vitreous, much may be done for the relief of the patient. If myopia is found to be their cause, its correction to the full degree of the error should be ordered. Irregularities of the menstrual function, disorders of the liver, or exhaustion from protracted illness of any kind must be corrected. For syphilitic varieties the mercurial preparations employed in the form of intramuscular injections promise more than when given in any other way. The protiodid of mercury, combined with iron, also gives excellent results, as do iodid of potassium and sodium. Gout, constipation, and anemia should be treated for the share they may have had in the production of the disease. Diaphoresis with pilocarpin hydrochlorate (gr. $\frac{1}{10}$ — $\frac{1}{6}$ hypodermically) is of service, and, according to de Schweinitz and Spaulding, small doses of the same drug, even when sweating is not produced, are valuable. Electricity in the form of galvanism has been reported to be of use.

Various medicinal agents, such as the soluble mercurial salts, solutions of potassium iodid, and carbolic acid, have been injected into the vitreous chamber in the hope that absorption of vitreous opacities and other effused inflammatory products might follow. The writer does not believe that such treatment is warranted, except where vision has been reduced to a mere quantitative perception of light, which no remedy, however severe, can make worse, for disorganization and dense opacity of the vitreous body are almost certain to follow its use. Furthermore, the hyaloid and retina become affected, and panophthalmitis usually results.

A large fixed and more or less central membranous opacity may be divided by passing a discission needle into the vitreous in front of the equator of the eye, entering it just below the lower border of the external rectus muscle, care being exercised to watch the movements of the instrument with the ophthalmoscope.

Pseudo-glioma, so called from its resemblance to glioma of the retina, is a circumscribed suppurative inflammation of the vitreous, generally occurring in the periphery of the chamber near the ciliary region.

With the ophthalmoscope a yellowish-white reflex can be seen, but as there are abundant evidences of a pre-existing irido-choroiditis, there can scarcely be excuse for mistaking this for a true glioma of the retina. Diminished tension, followed by shrinking of the globe, sometimes with subsequent ossification of the choroid, marks the distinction between this and true glioma.

The treatment is to be directed to the primary disease standing in a causal relation to this affection (see also page 355).

Muscae Volitantes.—*Myodesopsia*.—There are in the vitreous certain ameboid cells, most abundant at its periphery, which are of normal occurrence, and are not disturbing to vision, as they are transparent and readily transmit light. On account of their constant presence the mind usually disregards them, but occasionally, when looking at some white surface, as the page of a book, and while there are no other retinal images with which to compare them, they force themselves upon the notice of the patient and cause more or less distress. They may be seen *entoptically* by closing the eyelids and turning the face toward a bright light. They appear as fine threads and specks of various size, which float across the field of vision when the eye is being moved, but do not in any way disturb visual acuity. Occasionally they assume curiously fantastic shapes.

Treatment.—As most patients annoyed by muscae volitantes have some

error of refraction, this should be corrected with suitable lenses. At the same time, they should be assured that the presence of these floating opacities has no clinical or pathological significance.¹

Hemorrhage into the Vitreous.—This most frequently follows a rupture of some of the vessels of the choroid at its anterior portion where the retina is thinnest, thus allowing a freer extravasation than would be the case should a vessel rupture at its posterior part, where the retina is thicker. Schweigger doubts if extravasation of blood into the vitreous can occur as the result of a rupture of the vessels of the retina, because, owing to the arrangement of its connective-tissue fibrillæ and the strength of its internal limiting membrane, hemorrhage from it would generally extend toward the choroid and not toward the vitreous. However this may be, we are able to see with the ophthalmoscope, if the hemorrhage is slight, a bright red reflex indicating the seat of the extravasation, or a red veil if the blood is thinly distributed over a considerable extent of the vitreous.

Spontaneous hemorrhage into the vitreous may occur, particularly in the case of young male adults who are subjects of irregularities of the circulation (Eales) and of gout (Hutchinson). Such hemorrhagic effusions are not, as a rule, entirely absorbed, but leave opacities in the vitreous very damaging to vision if centrally situated.

If the hemorrhage is extensive, the sight is immediately lost, and it is impossible to obtain a view of the interior of the eye. After absorption of the effused blood, and when the vitreous has become clear, numerous fixed and floating opacities may be seen, which become less and less distinct as absorption goes on, only to be followed by other extravasations, and perhaps finally by detachment of the retina. Permanent opacities are usually left behind, even in those cases where the hemorrhages do not recur, and vision is always very considerably impaired.

Treatment.—The mercurial preparations, iodid of potassium, pilocarpin, and the saline mineral waters are indicated in the treatment of these cases. Ergot may also be employed, especially early in the disease. Abadie has directly galvanized the vitreous, passing a platinum needle in the chamber, in a case of chronic vitreous hemorrhage. This procedure is of doubtful value.

Synchisis Corporis Vitrei (*Fluidity of the Vitreous*).—During the progress of certain diseases of the eye, notably retinitis, choroiditis, and very high degrees of myopia, the nutrition of the vitreous is so seriously impaired that its proper framework is destroyed, and it loses its normal consistency and becomes a straw-colored liquid. In extracting a cataractous lens we frequently have to guard against this condition, which has been developed by a previously existing disease of some other part of the eye. There are always diminished tension, and frequently a tremulous condition of the iris. Treatment is of no avail.

Synchisis Scintillans (*Cholesterin Crystals in the Vitreous*).—The presence of minute crystals of cholesterin and tyrosin in the vitreous produces a very interesting ophthalmoscopic picture, but does not interfere with vision if that body is otherwise healthy. The crystals are seen in the

¹ For an interesting and suggestive study of muscæ the reader is referred to a paper by Geo. M. Gould, M. D. (*Medical News*, Sept. 15, 1895). Dr. Gould believes that there is a chamber, which he calls the aqueo-vitreous chamber, situated between the vitreous posteriorly and the lens, its ligament, and the ciliary body anteriorly, and which contains the muscæ-genetic particles in suspension. These particles he regards as the débris of vitreous katabolic change. Based on entoptical studies, Dr. F. P. Pratt believes that so-called muscæ are caused by the lymphatic capillaries of the vitreous.

eyes of the aged, usually in connection with vitreal opacities. They are not of frequent occurrence. They appear as small luminous bodies which reflect the light from the ophthalmoscope in the form of a shower of sparks, and do not yield to treatment.

Blood-vessel Formation in the Vitreous.—Observation with the ophthalmoscope has occasionally revealed the formation of new blood-vessels in the vitreous, and their presence is presumptive evidence of a previously existing inflammation of that body or of former hemorrhages. Becker relates that he observed them in a case of purulent infiltration of the vitreous, while Hirschberg has seen them in connection with specific disease of the eye. They start from the nerve-head, which they partly obscure, and pass

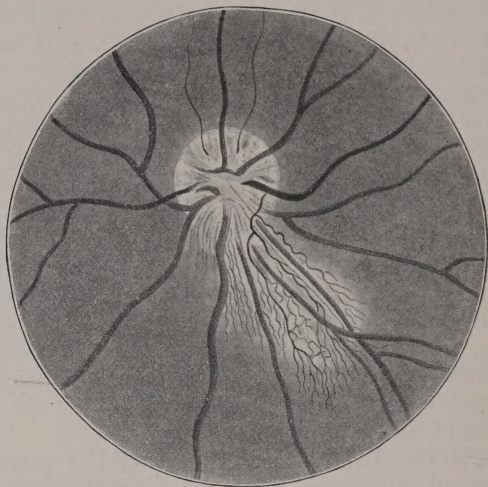


FIG. 256.—Blood-vessels in the vitreous (Hirschberg).

forward into the vitreous as a more or less well-formed veil of freely communicating capillaries, without, however, having any connection with the vessels of the retina (Fig. 256).

Entozoa in the Vitreous.—Two distinct parasites have been found in the vitreous of the human eye—the *cysticercus cellulosæ* and the *filaria sanguinis hominis* (Manson).

The former, while rare, has been seen most frequently in North Germany. It is the scolex of the *tænia solium*, the eggs of which, having obtained entrance into the stomach, find their way into the blood-channels, whence they are carried to the eye and deposited under the retina. In the course of its development it is provided with hooklets, by means of which it perforates this tunic and is set free in the vitreous. Here it may appear encysted in a membrane which will mask its distinctive characteristics and prevent a correct diagnosis. If, however, it is quite free, it is of a pale, greenish-blue color, having a short neck surmounted by a round head ornamented with minute suckers, which may be seen to move in undulating lines.

Von Graefe attempted the removal of a *cysticercus* through an incision, following his method of the extraction of a cataractous lens. After delivery of the lens he passed a blunt hook into the vitreous, and by alternately advancing it toward the entozoon and then withdrawing it, he succeeded in delivering the parasite, without, however, restoring vision.

The *filaria sanguinis hominis* in the human eye is of such rare occurrence that it requires only passing mention.

Detachment of the Vitreous.—The vitreous is subject to degenerative changes which produce a shrinkage in its volume, thus removing it from direct contact with, and support of, the limiting membrane of the retina. As is readily seen, this condition is followed by detachment of the retina and loss of vision. The author has enucleated a painful atrophied eyeball in which this condition was beautifully illustrated. The vitreous had shrunk to half its size, and was closely enveloped by the retina, and consisted of bands of connective tissue stretching from the nerve-head to the posterior surface of the lens. This condition results from injury to the vitreous, followed by choroiditis and hemorrhage, or from extensive posterior staphyloma. The treatment is enucleation.

Fatty Degeneration of the Vitreous.—Under this heading Dr. D'Ench and Dr. Valk have reported cases the diagnostic features of which

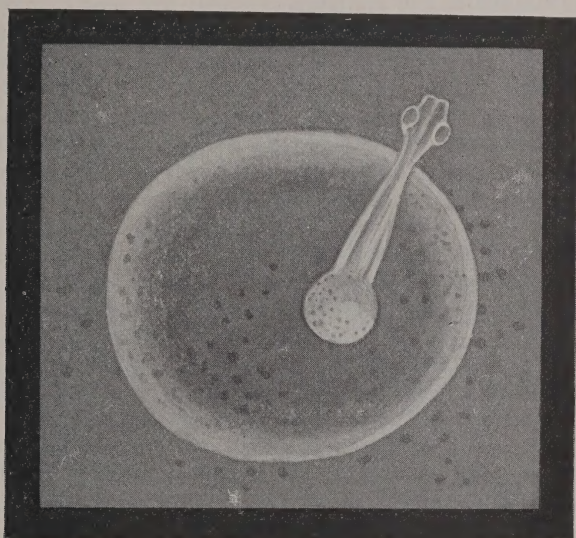


FIG. 257.—Cysticercus in the vitreous (Liebreich).

seem to resemble those described by Iwanoff and called by him fatty degeneration of the stroma and cells of the vitreous.

The ophthalmoscope furnishes a picture of numerous white, glistening spots very evenly distributed throughout the vitreous, and having slight motion when the eye is moved—not, however, an independent motion, but one seeming to depend upon the quivering or tremulousness of the normal vitreous when the eye is quickly moved in any particular direction. Iwanoff does not regard this condition as a pathologic change, but a quasi-physiologic state due to senile decay. The vision is slightly reduced, but not to an extent requiring special treatment, further than the correction of any existing error of refraction.

Persistent Hyaloid Artery.—The *hyaloid artery* (an extension of the central artery of the retina) during fetal life passes from the optic nerve-head forward across the vitreous body, sometimes terminating in the vitreous and sometimes extending as far forward as the posterior surface of the lens. It

occupies a canal (the *canal of Cloquet*), which, with the artery, shrivels up and disappears about the sixth month of gestation. (See page 24.)

In exceptional cases, however, it remains, and, according to De Beck, may be seen floating in the vitreous in one of the following forms: a filamentous strand attached to the disk, the free end floating in the vitreous; a strand attached to the lens, and the end floating in the vitreous; a strand attached to the disk, and a like strand to the posterior surface of the lens, each terminating in the vitreous; a strand passing across the vitreous and attached to the disk and the lens; a distinct vessel containing blood, passing entirely across the vitreous; and the canal of Cloquet, not containing any vessel.

The remains of this artery are also sometimes seen as irregular minute bodies on the surface of the disk, and its vestigial remains doubtless produce that variety of congenital cataract called posterior capsular cataract (page 389) when situated on the posterior surface of the lens. (Consult Figs. 137, 138 on pages 190, 191.)

DISEASES OF THE RETINA.

By LUCIEN HOWE, M. D.,

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Congenital Peculiarities of the Retina.—As it is often difficult to define the limit between health and disease, it becomes an important question to determine what should be considered a normal retina. Therefore attention is first directed to those congenital peculiarities which cannot be classed as pathological. These are usually described last in chapters on the retina, but some repetition and confusion are avoided if they are considered first.

Such variations from the normal type are to be seen (1) in the vicinity of the optic nerve; (2) in the retina; and (3) in the macula.

First.—Variations near the nerve are due to—

(a) *Insufficient pigment*, which should not be confused with the actual atrophy of the retina and choroid in the vicinity of the nerve. The latter diseased condition shows itself as a crescent more or less marked, or even as a complete white circle (see Fig. 136).

(b) *Excess of pigment* may be seen in brunettes, and sometimes amounts to a dark, well-marked ring of deposit about the nerve.

(c) *Absence or abundance of blood-vessels* at the edge of the nerve may simulate disease and yet be within normal limits.

(d) *Opaque nerve-fibers* may present an appearance which at first glance may be mistaken for neuro-retinitis. It is well to bear this in mind in connection with that disease (see also pages 189, 190, 194).

Second.—Variations in the retina are due to—

(a) *Insufficient Pigment.*—When of slight degree this gives rise to a peculiar appearance in which the vessels of the choroid simply become unusually prominent. When, however, pigment is lacking entirely, as in albinos, a network of vessels distributed over a pink or an absolutely white field is apparent.

(b) *Excess of Pigment.*—In this condition the fundus is not only dark and the vessels difficult to distinguish, but occasionally the pigment is unequally distributed, giving rise to a peculiar mottled appearance. In some of these cases the choroidal vessels are particularly prominent, manifesting themselves as red lines distributed over rather a dark field.

Any of the above variations from the usual type are easily recognized as physiological, unless the diminution or excess of pigment is confined to a certain part of the retina, when it may give to the fundus an appearance which is readily mistaken for an abnormal condition.

Third.—Variations in the macula.

In typically normal eyes nothing can be seen of the macula except the red reflex of the fundus, the area usually being darker than the rest of the background and uncrossed by retinal vessels. But there are variations from this which should be noticed. In blonds and in retinas having an unusually small amount of pigment the macula can often be distinguished as a light

spot on a darker field, its edges being well defined, or, again, as a dark area, the edges of which blend imperceptibly with the red of the retina near it. The latter is the more common form. In exceptional cases the macula is dark, and its edges are marked by a ring (macular reflex), the center being then light or almost white (foveal reflex) (see also page 188).

Small, white, glistening dots are occasionally found in the vicinity of the macula. These are known as "*Gunn's dots*." Sometimes they are quite numerous, but they do not interfere with perfect vision. They are to be taken into account in making a differential diagnosis in cases of commencing albuminuria.

A simple and easy plan of studying the diseases of the retina is to begin with disturbances of the circulation—*First*, when the supply of blood is diminished, as in anemia, or entirely shut off, as in embolism; and *second*, when the supply is simply increased, as in hyperemia, or increased with other signs of inflammation. This will lead to the consideration of the various forms of retinitis, after which will follow a description of degenerative changes.

Anemia of the retina means properly that the lack of blood is merely the local expression of a general condition, while *ischemia* indicates that the causes of the altered circulation are in the eye itself.

Etiology.—Retinal anemia occurs in ordinary syncope or from any cause—as, for example, vaso-motor spasm—which contracts the arteries of the brain or lessens the amount of blood sent there. Retinal anemia, with contracted arteries, may occur in migraine, and may be associated with hemianopic blindness.

Symptoms.—While very marked decrease or increase in the blood-supply of the retina can be distinctly recognized, it must be admitted that the slighter variations from the normal standard are not easily diagnosed. However, the contracted vessels, the lighter color of the retina, the unusual whiteness of the nerve, and the functional disturbances, if present, tend to establish the diagnosis.

Treatment should be directed to the removal of the cause producing the general anemia. As strychnin has long been used hypodermatically for a diminished supply of blood in the optic nerve, as in atrophy, so has it been suggested for the same reason in retinal anemia. Nitrite of amyl may be used to relieve spasm of the arteries of the retina. A method of treatment well worthy of trial is to arrange the position of the patient, for as long a time daily as can be borne comfortably, so that the head is lower than the rest of the body. The contracted or emptied vessels of the retina are filled by the force of gravity.

Embolism of the Central Artery of the Retina.—**Etiology.**—The most frequent cause of embolism is valvular disease of the heart, especially when complicated with fresh endocarditis. It also occurs with various forms of arteritis, with aneurysm of the aorta and carotid, with Bright's disease, and with pregnancy; occasionally it complicates chorea. It may occur at any period of life, and has been recorded from the fifteenth to the eightieth year. Simultaneous embolic plugging of the central artery in each eye has been described, but it is an exceedingly rare condition. It is more frequent on the left than on the right side, and has occurred more times in men than in women.

Pathological Anatomy.—In the earliest case observed with the ophthalmoscope (von Graefe) an opportunity was afforded to secure a post-mortem examination one and a half years later (Schweigger). Sections of

the eye showed that the central artery was completely blocked just behind the lamina cribrosa. The embolus may be granular in nature, or consist of a hyalin plug, or may be covered with layers of endothelium. Sometimes it only partially blocks the lumen of the vessel; at other times it completely occludes its caliber. Atrophic changes may be found in the retina, the optic nerve, and the choroid, according to the date of the examination after the embolus has occurred.

The clot does not always block the central artery itself, but may lodge in one of the branches of the main retinal artery, and there produce over a limited area the same symptoms, the same appearance, and the same pathological conditions which are found when the central artery is affected.

Re-establishment of the circulation may occur because the lumen of the blocked vessel again becomes free, and the presence of cilio-retinal vessels may be the means of preserving good acuity of central vision. According to Ward Holden, with single embolism of a branch of the central retinal artery there may be a field of irregular form which to a considerable extent is explainable by variations of the arterial distribution, and in cases where the lumen of an artery remains blocked there may be a collateral restoration of its circulation by anastomosing vessels.

Symptoms.—The patient may be entirely ignorant of the existing condition if the embolus occurs in one eye only, for there is no special pain nor other peculiarity following, which calls attention to the difficulty, except the loss of vision, which occurs with characteristic suddenness. In other cases, however, the subjective symptoms in the form of a species of aura are peculiar. There are scintillations before the eyes or dark rings appear. In a very typical case which the writer observed the patient remembered peculiar flashes which called her attention to the rapidly departing vision.

The ophthalmoscopic picture is quite characteristic, being that of an almost pure and well-marked *ischemia of the retina*. The arteries are small, and the corresponding veins considerably reduced in size, or they may reveal unequal distention, the terminal endings of both being to a great extent lost. Pressure from before backward causes a regular current to flow through the vessels, which consist of broken cylinders of blood separated by clear spaces, moving sluggishly along. In the veins, directly after the lodgement of the embolism, an *intermittent blood-stream* is often visible. The optic disk is blanched almost as it appears in atrophy, and the retina, especially in the neighborhood of the papilla and the macula, is of a whitish appearance (the so-called *fog-like edema*), in marked contrast with that of the other eye. A very characteristic feature of this disease is the color of the macula. The rest of the retina may appear of a normal color or even decidedly whitened, but the macula stands out in contrast with its surroundings as a clear *cherry-red spot* which attracts attention at the first glance. The reason for this peculiar color is by no means fully explained. The general conclusion, however, is that it is not entirely an extravasation, but is due partly to an engorgement of the choroidal vessels beneath the macula, and partly to the effect of contrast which this spot then presents to the neighboring retina (Loring). There are also changes in the pigment epithelium. In dark-skinned races the cherry spot may be replaced with a coal-black one. This macular appearance is more apt to arise in stoppage of the main trunk than when only a branch is plugged. Occasionally, if the embolus lodges in a branch of the main artery, it is visible to the ophthalmoscope as a small yellowish body, or it may be assumed to be present because at one point in the artery there is a swelling, while beyond it the vessel is obliterated or

greatly contracted. In the course of several weeks, in complete cases, the retinal edema subsides, the disk undergoes atrophy, and the vessels are converted into white lines.

The *subjective symptoms* are, in complete cases, sudden loss of vision, unless the presence of a *cilio-retinal vessel* permits the preservation of good acuity of sight, as reported by Wadsworth, and occasionally headache and giddiness. According to C. F. Clark,¹ the evidence is not sufficient to warrant the conclusion that true cilio-retinal vessels are the means of preserving the integrity of the papillo-macular region of the retina. In obstruction of a branch, vision may be very good, or, indeed, even normal. The *field of vision* depends upon the extent of the circulatory obstruction. If only a branch has been occluded, that portion of the retina which receives its blood-supply from this source will be paralyzed and the opposite area of the field darkened. Occasionally there is a central scotoma. The tension may be raised, lowered, or normal.

Diagnosis.—These cases may simulate anemia of the retina, because the condition of the heart produces some general anemia, but the history is usually sufficient to separate one disease from the other. While the ophthalmoscopic appearances already detailed indicate interruption of the retinal circulation, it is often difficult, and even impossible, to distinguish between thrombosis and embolism of the artery. Similar appearances may be produced by hemorrhage into the sheath of the optic nerve (see page 453).

Prognosis.—This depends upon the rapidity with which the collateral circulation is established, a greater or less tendency to this being apparent almost from the first. In complete embolism of the central artery the prognosis is most unfavorable.

Treatment.—Paracentesis has been tried in order to change the amount of blood-pressure, but in general more depends upon improving the condition which has caused the embolus than upon any attempts at local medication. Nitrite of amyl inhalations are recommended by Gifford, and massage of the eyeball, in the hope of dislodging the embolus, should be faithfully tried. This has been effected in some cases.

Thrombosis of the Retinal Artery.—Thrombosis may occur under the same conditions which are active in the production of embolism, and the thrombus may form either in the central artery itself or in one of its branches.

Ophthalmoscopically, it is difficult or impossible to distinguish between thrombosis and embolism. According to Priestley Smith, previous attacks of temporary blindness in the affected eye, a simultaneous attack of temporary blindness in the unaffected eye, giddiness, faintness, and headaches are apt to be associated with thrombosis, and not with embolism.

The *treatment* is the same as that recommended for embolism.

Hyperemia of the Retina.—By this term is understood an abnormal and equal increase in the amount of blood throughout the entire retina. Hyperemia of the larger blood-vessels is easily recognized. When, as is usual, this is accompanied by *capillary hyperemia*, the condition is indicated by a change in the color not only of the retina itself, but especially of the surface of the optic nerve, which becomes redder than normal. Should the hyperemia exist in a marked degree, the overflowing arteries have a tortuous appearance, such as would naturally be expected when an elastic vessel is filled beyond its normal capacity. Two forms of hyperemia are to be distinguished, the active and the passive.

1. *Active hyperemia* may be produced by a variety of causes. One of

¹ *Archives of Ophthalmology*, xxvi. 1897, pp. 395-404.

these, for example, is long-continued effort at accommodation, especially when made by artificial light or when the refractive condition of the eye necessitates an unusual amount of straining of the ciliary muscle. De Wecker has noticed that a solution of the tincture of opium dropped into the conjunctival sac will also produce a certain amount of active hyperemia. It is commonly present in eyes exposed to glare of light and heat—*e. g.* in puddlers. The same condition occurs in several of the inflammations of the eye, especially when the uvea is involved.

Symptoms.—These are more or less pronounced, varying from slight sensations of discomfort to considerable photophobia and lack of eye-endurance.

Diagnosis.—This is not so easily made as might be imagined. As the subjective symptoms, even if present at all, are usually by no means prominent, the diagnosis in a large proportion of cases must be determined by the ophthalmoscopic appearance. But it should be borne in mind that the blood-supply to the retina may seem to vary from the normal standard when in reality this is not the case. In some individuals the retinal vessels are much more abundant than in others, just as we find complexions of a florid type or with decided pallor. Particularly does the condition of the refraction change the apparent size of the vessels when examined by the ophthalmoscope. Again, a decided astigmatism may distort the vessels in different meridians. Indeed, the beginner with the ophthalmoscope must be careful not to fall into the common error of diagnosing a "*retinal congestion*" when, in reality, there is nothing of the kind present. Only a careful study of the case, with due regard to errors of refraction, will enable one in certain instances to decide as to the presence or absence of hyperemia of the retina.

2. *Passive Hyperemia.*—Any cause which interferes with the egress of blood from the eye may produce this condition; for example, in glaucoma, where, as a result of the pathological condition accompanying that disease, the veins are enlarged to a considerable degree, the finer branches are more numerous, and the larger trunks more tortuous, especially near the margin of the papilla. Another example is furnished by the condition known as "*choked disk.*" Stasis hyperemia is also present in mitral disease, emphysema, convulsive seizures, and, indeed, in any state which prevents the veins of the head and neck from emptying their contents into the venous channels of the chest.

Symptoms.—These are similar to those which occur in active hyperemia. The same care should be exercised in making the diagnosis, although in this form, mistakes are not so liable to occur as in active congestion.

The prognosis and treatment depend upon the causes.

Somewhat analogous to *congestion* or *hyperemia of the retina* is the condition known as *hyperesthesia of the retina*, or, to employ the term suggested by Jaeger and Loring, *irritation of the retina*.

Ophthalmoscopically, may be seen undue redness of the nerve-head, veiling of its nasal margins, and delicate edema of its surface. Often the entire fundus is ill defined, and the details of the background of the eye are imperfectly seen.

Etiology.—Cases of this character are caused by errors of refraction and anomalies of muscle-balance. They are often associated with chronic headache, neuralgia, and their subjects suffer from photophobia, blepharospasm, and marked asthenopia. In some instances there appears to be a distinct relation between retinal irritation and changes in the naso-pharynx, particularly those characterized by a hypersensitive mucous membrane and vaso-

paretic and infiltrated turbinals. Loring believes that retinal irritation may be a forerunner of organic optic-nerve disease.

Anesthesia of the Retina (*Neurasthenic Asthenopia*).—This condition is really a symptom of a complicated neurosis rather than a special disorder of the retina. Its phenomena have been specially studied by Wildbrand, who records the subjective symptoms as follows: Peculiar contraction of the field of vision, indicating retinal fatigue and the development of the so-called *counter-field* (see page 486); rapid disappearance from view of any object which is fixed; diminution of central vision; sudden attacks of obscuration of vision and processions of scotomas; visual hallucinations; lack of fixation of the optical memory-images; and marked asthenopia. The subjects of this affection are chiefly women, and often those afflicted with ovarian and uterine disease, hysteria, and chlorosis. Pure types are also seen in men, and are often connected with sexual derangements.

Treatment.—This must be directed toward the general condition, although any error of refraction should be corrected and the proper glasses worn constantly. It must be remembered that neither in this type of retinal affection nor in hyperesthesia of the retina are spectacles alone sufficient. A consideration of the etiological factors only will supply indications for the proper constitutional and local measures.

Thrombosis of the retinal veins has been observed as the result of syphilis and with heart-disease. Thrombosis of the central vein is sometimes seen with hemorrhagic retinitis, of which it may be the cause, and also in a few other conditions in which the walls of the veins have undergone some degeneration.

Symptoms.—As these lesions can be seen ophthalmoscopically, it is natural to expect with them certain symptoms more or less well marked. These are a scotoma of varying size, corresponding in extent and location to the part affected by the thrombus, and usually floating bodies in the vitreous (*hyalitis*), causing *muscæ volitantes*. Complete thrombosis of the central vessel causes great engorgement of the veins, interrupted venous circulation, strong venous pulse, streaked disk-margins, and numerous retinal hemorrhages.

The diagnosis is comparatively simple when the vitreous is sufficiently clear to enable the lesions to be recognized by the ophthalmoscope.

No local treatment is of any value, but potassium iodid, mercuric chlorid, and other alteratives may be given to encourage absorption of the effused blood.

Telangiectasia of the retinal vessels, aneurysm of the central artery, and varicose veins of the retina have also been observed, but they are so rare as to deserve only mention here. They show, in general, that while we have in hyperemia the first step toward a real inflammation, the vessels of the retina also undergo the same variations from the normal standard as occur in other parts of the body.

Retinitis.—Under this general term are included the various types of inflammation of the retina.

Forms of Retinitis.—These are not always properly described by the names given to them, nor is the term itself always exactly applied. Thus, it sometimes expresses a pathological condition—for instance, serous, parenchymatous, or suppurative retinitis; or it is used to denote the results or accompaniments of such inflammations—for example, hemorrhagic retinitis; or, again, it is employed to describe the cause—*e. g.* syphilitic or albuminuric retinitis. Again, retinitis pigmentosa and other names indicating inflammation

are given to retinal lesions which are not inflammations at all, in the true sense of the word. Therefore, it is desirable to keep in mind the three types of inflammation to which the retina is subject—namely, the *serous*, the *parenchymatous*, and the *purulent*.

These types, more or less modified, are met with in conjunction with certain systemic conditions: thus the serous type is often found with syphilis, while the parenchymatous type occurs principally with changes in the kidneys. The different retinal inflammations can best be understood, therefore, by considering these types first, and later their modifications, after which another group—the scleroses—of which the so-called retinitis pigmentosa is a type, will be described. That is, all forms of retinitis may be arranged into four groups:

I. *Simple or Serous Retinitis*.—Allied to this are—

- (a) Syphilitic retinitis;
- (b) Sympathetic retinitis;
- (c) Retinitis from concussion.

II. *Parenchymatous Retinitis*.—In this are included—

- (a) Albuminuric retinitis;
- (b) Diabetic retinitis;
- (c) Leukemic retinitis;
- (d) Syphilitic chorio-retinitis;
- (e) Hemorrhagic retinitis;
- (f) Macular retinitis.
 - α. Retinitis albescens;
 - β. Retinitis circinata;
 - γ. Solar retinitis;
 - δ. Symmetrical changes at the macula lutea.

III. *Embolie or Septic Retinitis*.

IV. *Retinal Sclerosis*.

- (a) Retinitis pigmentosa, typical form;
- (b) Retinitis pigmentosa, atypical form;
- (c) Retinitis proliferans.

Serous Retinitis (*Retinitis Simplex*; *Edema of the Retina*; *Peripapillary Retinitis*).—Retinal inflammation of slight degree, marked only by hyperemia and exudation, is known as *simple retinitis*. When, however, there is besides an alteration of the deeper tissues (hyperplasia), the term *parenchymatous* is used. It is evident that the two forms may merge into each other by imperceptible gradations under certain circumstances, and that a process which begins as simple retinitis may pass into the parenchymatous form. Practically, however, the first type or stage retains its own characteristics so constantly that it may be properly considered a distinct disease.

Varieties.—As the retinitis may vary according to the depth to which the layers are invaded, it may also vary in the extent superficially or in the secondary changes accompanying it. When the edema is limited to that region where the retina is the thickest—namely, about the edges of the optic nerve—the appearance presented is so peculiar as to warrant the name *peripapillary retinitis*.

Diffuse retinitis is more common. The edema, extending over the entire retina, veils to a greater or less extent the features of the fundus.

Etiology.—The causes to which simple retinitis has been ascribed are

manifold. Among these have been enumerated excessive use of the eyes under unfavorable conditions, refractive error, dazzling light, exposure to cold, chill, etc. In many cases, however, it is due to syphilis. It may be the initial change of other forms of retinitis presently to be described.

Pathology.—The term inflammation ordinarily is applied to nutritive disturbances accompanied by redness, swelling, heat, and pain; but it is necessary to modify this definition in accordance with the alterations to which this pathological process is subjected by the different structures of the body in which it occurs. Especially is this the case in retinitis. In the early stages of the inflammation a hyperemia, more or less well defined, is present. This corresponds to the redness which accompanies an inflammation elsewhere. As a result of the distention of the vessels there is naturally edema, with some infiltration of the leukocytes into the inner layers of the retina, particularly into the nerve-fiber and ganglionic layers, or even into the vitreous humor. Similar lesions would produce swelling if they occurred in other portions of the body. These two pathological changes constitute practically all which are present in pure, simple retinitis.

Objective Signs.—The ophthalmoscopic changes are as slight, proportionately, as are the pathological alterations. They are—

(1) *Edema of the retina.* The features of the retina can usually be distinguished, but they appear as if seen through a mist. The retina often has a somewhat grayish aspect, almost invariably the vitreous is more or less clouded by the infiltration, and the details of the retina are consequently indistinct.

(2) *The vessels, especially the veins, are altered.* They are more tortuous and have a greater number of branches than usual. They are distended at some points or disappear under the swollen retina at others. Sometimes the arteries appear reduced in size from compression.

(3) *Hemorrhages* are occasionally met with, but are not common with the serous variety of inflammation; nor, indeed, are any other of the more extensive alterations present which are found when the deeper layers of the retina are affected.

Subjective Symptoms.—(1) The first and most important symptom is a diminution in the acuity of central vision, often associated with greater or less contraction of the field. Occasionally, in the circumscribed variety of retinitis, only one spot is involved, perhaps near the equator, and then not only is it easily recognized because of the contrast which this area presents to the surrounding tissue, but an exact examination of the field shows a well-defined scotoma corresponding to the affected part.

(2) Distortion of vision due to the altered retina. The exudation into the retina changes the position of that membrane more or less, and, together with the unequal pressure upon the rods and cones, produces peculiar distortions of the retinal image. Thus, objects may appear larger than normal (*megalopsia*), or the patient may describe them as being distinctly smaller (*micropsia*), or, finally, they may be distorted in various ways (Loring). When the difficulty exists in both eyes it is not always easy to decide what the peculiarities are in each, unless one eye be covered or diplopia is produced with a prism.

(3) A symptom occasionally present in this type of retinitis is the ability to see better by imperfect illumination—for example, in the evening—than where the light is bright. This condition has been called by Arlt *nyctalopic retinitis*. Evidently, however, it is only a symptom.

(4) As there are no sensitive nerve-fibers in the retina, often a high

degree of inflammation passes without pain, imperfect and distorted vision being about the only symptoms which attract the attention of the patient.

Diagnosis.—This is easily made, especially in cases not far advanced, there being then no danger of confusing the serous with the parenchymatous form. The veiling of the fundus when the inflammation is *diffuse*, or the grayish patches when it is *circumscribed*, together with the changes in the vessels, or swelling of the retina, with the corresponding diminution of vision, furnish a characteristic picture.

Prognosis.—This is uncertain and depends somewhat upon the cause. It can never be safely foretold that a serous inflammation thus begun will not assume the parenchymatous form. When the inflammation is not present in a marked degree, or when it has existed for a comparatively short time, absorption is apt to take place; or when the serous inflammation is dependent upon syphilis the prognosis is more encouraging, inasmuch as this variety frequently yields readily to treatment.

Treatment.—Whenever the cause can be determined, it is of course necessary to combat that first. Where there is a distinct history of syphilis, or when the serous retinitis is apparently connected with any systemic disturbances, the plan to be pursued is plain enough; but, unfortunately, the causes are by no means always clear, and in those cases only local treatment remains. Usually much attention is given to protecting the eyes from bright light, colored glasses or even a dark room or a bandage being advised; but in this disease, as in others requiring confinement in a dark room, the patient should be given a certain amount of exercise daily in the open air. The artificial leech, cold applications, and, in general, an antiphlogistic form of treatment are advisable in inflammations of the sthenic type. Mydriatics are not usually mentioned in this connection, but it is undoubtedly the case that atropin often assists in keeping the eye entirely at rest, and, although the dilated pupil allows more light to enter the globe, the improvement following the use of atropin is too common to warrant its omission.

Syphilitic Retinitis (*Specific Retinitis*).—It is a question whether an inflammation of the retina occurs primarily as a result of syphilitic infection. Desmarres, among the French, and the English practitioners generally, are inclined to regard syphilis as commencing always in the choroid, and affecting the retina only secondarily. However this may be, a serous inflammation of the retina often results from syphilis.

In the pathological anatomy of this disease there is nothing sufficiently characteristic to distinguish it from serous retinitis due to other causes. Still, one peculiarity may be remarked—viz.: a tendency of the inflammation to be circumscribed instead of general. For this reason it is also known as *retinitis with exudative spots* (Galezowski), but these may exist at the same time with considerable general edema of the retina.

Symptoms.—The ophthalmoscopic picture is such as has been described under Serous Retinitis, varied only by the *local edemas* which are common in addition to the *diffuse exudation*. This, as before stated, obscures the whole fundus more or less, rendering indistinct the outline of the disk and the course of the arteries and veins, which are veiled by lines of grayish opacity. The papilla is discolored, and has been compared to a yellowish-red oval seen through a covering of fog (Plate 5, Fig. I.).

The *subjective symptoms* are also the same as those of simple retinitis. The "mist" before the eyes thickens slowly, and usually steadily. While there is no decided pain in the eyes, photophobia is sometimes present, and photopsies and scintillations are common. Indeed, some authors consider the

last-named symptoms as regular accompaniments of the serous form of syphilitic retinitis. Irregular and concentric contraction of the visual field, as well as various forms of scotomas, are commonly to be observed.

Date of Occurrence.—Diffuse syphilitic retinitis may occur in congenital and acquired syphilis. In the acquired form of the disease it appears from one to two years after infection, sometimes as early as the sixth month, and, according to Alexander, is found in about 8 per cent. of the patients. One eye alone may be affected, but usually the second eye is also involved.

Diagnosis.—There is no appearance or symptom diagnostic of syphilitic retinitis. The tendency to develop circumscribed spots of edema, in addition to the diffuse exudation, may perhaps point to syphilis, but a history of the case giving conclusive evidence of the general infection is the only testimony on which reliance can be placed.

Prognosis.—This is much more favorable than in cases of retinitis arising from other sources.

Treatment is of course governed by the cause; for, although the same precautions are to be taken locally as in serous retinitis, much depends upon the antisyphilitic remedies. Hirschberg insists that it is not safe to rely on potassium iodid, and that mercurials should always be given, for they probably have a beneficial effect upon such forms of inflammation, in addition to their specific action. The use of tonics is also desirable, and every effort should be made to improve the general condition of the patient.

Central relapsing retinitis, a rare form of syphilitic retinitis, appearing in the form of gray or yellow areas in the macula, or as numerous yellowish-white spots and pigment-dots, or as a diffuse opacity of this region, is a late manifestation of syphilis. Relapses are frequent.

Sympathetic Retinitis.—Before leaving this group of retinal inflammations mention should be made of that form which accompanies sympathetic iridocyclitis (Graefe). While the ophthalmoscopic appearances and symptoms of this variety are virtually the same as in other forms of serous retinitis, this is specially important as being sometimes one of the early manifestations of approaching sympathetic ophthalmitis. Its recognition furnishes indications as to the advisability of removing the eye first affected, should that question arise (see also page 348).

Concussion of the Retina (*Commotio Retinae*; *Edema of the Retina*).—This condition may follow injuries of almost any variety, but especially a blow on the eye from a cork, rubber ball, or other similar substance. It is characterized by slight retinal changes and more or less loss of vision.

The **pathology** of this condition has not been satisfactorily settled, for in some cases blindness results when the ophthalmoscope shows an almost normal retina, and in others very marked variations from the standard of health seem compatible with good vision. Whatever other effects may be produced by the injury, it is certain that after the blow—which is not necessarily directly on the eye—there often appear small points of edematous exudation in the retina, or these may coalesce, and the typical cloudy exudation seen in serous retinitis may cover a considerable area of the fundus.

Corresponding to this or extending beyond it is a *scotoma*, more or less well marked. Such an exudation can be seen best a day or two after the injury, but ordinarily it soon begins to absorb, and, though it may disappear entirely, the blindness, partial or total, may persist. Decided retino-choroiditis, the result of concussion, may occur. These cases are often of interest from a medico-legal point of view, and when malingering is suspected

the tests for detecting that must be made with unusual care. An important complication in these cases is the development of transitory astigmatism.

The treatment locally is similar to that for edema of the retina. Stress is laid on the good effect of long-continued mydriasis (see also page 364).

Parenchymatous Retinitis (*Retinitis Perivascularis*).—In the serous type of retinal inflammation, as already stated, hyperemia and edema are present, but little or no further structural change. When, however, there is hyperplasia, and when the deeper parts of the membrane become affected, the condition is generally called *parenchymatous* inflammation. It will be seen at once that in some respects this is like the type just mentioned, except that this process is more advanced.

Etiology.—The causes are sometimes easily traced, especially when dependent upon albuminuria, intracranial disorders, or certain general diseases, but at other times they are difficult to determine.

Pathology.—The same changes occur as in the serous variety—namely, hyperemia with edema, but the latter is frequently wanting, and there develops instead an infiltration of cells or metamorphosis of the connective tissue. This infiltration takes place, by preference, in the inner granular or in the intergranular layer (Arlt). At the same time alterations occur in the walls of the capillaries. It has not yet been clearly established which is cause and which is effect; and from the fact that the walls of the vessels so often undergo degeneration, this form of retinitis has also been called *retinitis perivascularis* (Iwanoff).

After these early stages there results—(1) an entire absorption of the inflammatory process; or (2) partial absorption with partial destruction (namely, *partial atrophy of the retina*); or (3) a *total atrophy*—i. e. the retinal elements pass into a form of cicatricial tissue, and other alterations go on in the nerve-tissues.

Ophthalmoscopic Appearances.—The vitreous being free from exudations, and edema usually being absent, the features of the fundus are distinct. The increased amount of blood causes the arteries to appear full, often tortuous, and the terminal branches extended, while the optic nerves take on a reddish hue. The veins give similar evidence of the hyperemia, and occasionally, as an accompaniment of such a distention of both arteries and veins, extravasations into adjacent tissues occur.

This is especially true in certain forms of retinitis of nephritic origin. In these cases the hemorrhages extend into neighboring parts of the retina as small reddish points. Where the vessel gives way through a considerable portion of its extent there results a linear extravasation. This form has been described as a separate kind of retinitis, called *hemorrhagic retinitis*. In fact, there is an endless variety in the position, form, and extent of these hemorrhages, so common in some types of retinitis.

Subjective Symptoms.—These are similar to those described in connection with serous retinitis. The same diminution of vision is always present, but in a much more marked degree. When the parenchymatous inflammation is general there may be total blindness, or, if it is circumscribed, there is a well-marked scotoma in the corresponding portion of the field.

Distortion of objects or similar visual disturbance is unusual, the retinal changes being too deep and extensive, but photopsies and scintillations are not uncommon. With this form of retinitis also there is no pain. Indeed, the advance of the disease is so entirely free from this symptom that when the inflammation affects only one eye the patient sometimes discovers the

blindness by chance, or often not until the same process in the other eye makes him aware of his condition.

Diagnosis.—A distinction between this and the serous form of retinitis is not difficult in typical cases, but there are intermediate stages in which it is unwise to decide with certainty. Indeed, it is possible to see the serous and parenchymatous type of inflammation present in the same retina at the same time.

Prognosis.—This is grave. Absorption does occur, and in certain instances normal vision returns, but this is very rare, except in the retinitis of pregnancy. In the large majority of cases the cell-infiltration is followed by connective-tissue changes, with subsequent atrophy, the vessels appearing later as whitish threads.

Treatment.—Locally this is the same as that already advised for serous retinitis. The general treatment depends on the systemic condition which is producing the disease.

Nephritic retinitis is a generic term including retinitis albuminurica and certain other forms of retinal changes accompanying diseases of the kidneys. These have been grouped under a single term, because they are the result of disease of the kidney, because the ophthalmoscopic appearances are similar and the pathological anatomy is in some respects identical. Diabetic retinitis is sometimes described under the same generic term, but inappropriately, as it is not the result of renal disease. For a clearer understanding of the subject it is better to consider each of these varieties in order.

Albuminuric Retinitis (*Retinitis Gravidarum*; *Renal Retinitis*; *Retinitis of Bright's Disease*).—This form of retinitis is characterized by imperfect vision, by definite ophthalmoscopic changes—among which those in the region of the macula are most noticeable—and by certain alterations in the structure of the membrane.

Etiology.—Even before Helmholtz gave us the ophthalmoscope, Bright, Landouzy, and others had called attention to the frequency with which so-called amaurosis accompanied albuminuria. It remained for later observers, however, to determine more exactly the dependence of one upon the other—a relationship which has been frequently and carefully studied.

If this disease is the result of albuminuria, the question naturally arises, Why do so few albuminuric patients complain of imperfect vision? The failure of vision usually escapes observation, because there is seldom or never any pain in the eyes, and, as the macula itself is often the last to be affected, the actual condition of the retina is neglected, attention being directed to other symptoms. But ophthalmoscopic examination of a large number of albuminuric patients, whether complaining of imperfect vision or not, indicates that the retina is affected in as many as one-fifth (Lécorché) or one-third of them (Galezowski). Indeed, it may happen, exceptionally, that the retinitis shows itself in a typical form before it is possible to detect albumin in the urine (Dixon, Abadie), as was illustrated also by a case reported by the writer.¹

Although chronic granular kidney is the usual cause of albuminuric retinitis, it also occurs with large white kidney and lardaceous disease. But attention should be directed specially to the albuminuria of pregnancy as a very frequent and important etiological factor. The relation between the two is as uncertain in this variety of the disease as in the former, but without doubt a considerable proportion of pregnant women who have albuminuria suffer also from the form of retinitis under consideration. Moreover, it is well known that

¹ *Trans. Med. Soc. State of New York*, 1893.

patients afflicted in this way during one gestation are apt to have a recurrence of the same symptoms when pregnant again. The fact that the retinitis may result in partial or total loss of vision, which can last permanently, even though the cause be temporary, indicates the importance of this phase of the subject. It will be referred to again when the question of treatment is considered.

Symptoms and Pathology.—The pathology can be studied to best advantage by first noting the symptoms and the ophthalmoscopic changes upon which these depend. It should be remembered, however, that the process is essentially a parenchymatous inflammation. The increased vascularity to be described later tends to result in hemorrhages, and while edema is slight and the vitreous clear, there is hyperplasia in the deeper layers or fatty degeneration of cells into those portions. Even a sclerosis of the nerve-fibers may also occur in spots (Müller).

The only local symptom of which the patient complains is imperfect vision. Sometimes this begins gradually and increases slowly; sometimes the onset is sudden and the advance rapid. The amount of inconvenience does not correspond necessarily to the extent of the retinitis, but rather to the degree in which the macula lutea is involved. Sometimes only the macula itself remains intact, and the patients are surprised to find that, although the central vision is practically normal, they are otherwise blind. The impairment of vision, like the retinal changes, is usually about the same in each eye; but *unilateral albuminuric retinitis* is not a rarity. The lesions may, exceptionally, remain monolateral till death. More commonly a monolateral case is converted after a time into the ordinary bilateral variety.

The ophthalmoscopic appearances of retinitis albuminurica are—

(1) *Fatty deposits*, more or less numerous, in the posterior segment of the retina. These white or yellowish-white plaques are usually well-defined, although the edges shade off gradually into the natural color of the retina. They may be limited to the vicinity of the macula from which they radiate, or may cover most of the posterior pole of the eye, according to the extent to which the retina is involved. Sometimes these spots of exudation are exceedingly small, with edges so sharply defined as to look like minute white dots. In nearly every case of retinitis albuminurica a group of these dots can be seen more or less completely surrounding the macula. In that vicinity their arrangement and form are so characteristic as to present a picture quite diagnostic of this disease. In the macula itself there is often a white spot, and almost invariably radiating from that point are numerous thin dashes of nearly glistening white which stream off in different directions, this appearance being due to the arrangement of retinal fibers (Schweigger). The lesion is sufficiently peculiar to be easily recognized when once seen (Plate 5, Fig. II.). If the average physician appreciated how readily this picture of retinitis could be detected, it is probable that the ophthalmoscope would be used much more frequently. Such spots about the macula may persist long after every other trace of the disease has subsided. This is especially the case in the albuminuric retinitis of pregnancy.

(2) The *retinal hemorrhages* which accompany albuminuric retinitis are peculiar. They are linear and flame-shaped, and they extend along the arteries, which are perhaps obliterated in parts, the extravasations being due primarily to changes in the walls of the vessels. Round, dotted, and sheet-like hemorrhages may also occur.

(3) Next to the alterations in the retina itself, those which involve the optic nerve should be mentioned. As would naturally be inferred, the edges

of the nerve become indistinct; it is often swollen, pushed into the vitreous, apparently, or streaked with diverging vessels; in a word, it presents the picture of *neuritis* or *papillitis*.

The foregoing is a description of a typical case, though of course each stage of its development can seldom be seen. Many variations occur. The disease may be characterized by small white spots, associated with comparatively inconspicuous hemorrhages in the fiber-layer—the so-called *degenerative* type; or it may manifest itself as a violent *neuro-retinitis*, with extensive hemorrhagic extravasations—the so-called *inflammatory* type. Sometimes comparatively small dots in the macula and single small hemorrhages may be the signs of renal retinitis.

Diagnosis.—This is not difficult in typical cases. To recapitulate, the chief signs are—(1) Imperfect vision in both eyes, either central, or with contracted field, or with scotoma. (2) Fatty deposits in the retina, especially in the vicinity of the macula. (3) Retinal hemorrhages, striated in form. (4) Secondary neuritis.

Prognosis.—This depends upon the variety and extent of the lesion in the kidney. It is comparatively good when the amount of albumin is slight or variable, as occurs in the milder forms of typical Bright's disease or frequently in the last stages of pregnancy.¹ The question becomes more serious, however, when the renal changes are extensive. Then the retina becomes more and more involved as the kidneys become disorganized, and the slowly but steadily increasing darkness foretells the fatal end. While the albuminuric retinitis of pregnancy usually ends with gestation or soon after, the prognosis in certain instances is grave in the extreme, for with vision greatly impaired, or perhaps lost, the patient may still live on for years.

Treatment.—Locally, there is little or nothing to be done. It is well to protect the eyes from bright light by means of colored glasses, and to abstain from prolonged efforts at accommodation, but with these instructions to the patient the therapy of the ophthalmologist ends. After that he may watch with interest the progress of the retinitis; he may prescribe iron, alone or with bichlorid of mercury, advise steam baths, etc.; but the important part of the treatment belongs rather to the province of the physician or, in certain cases, to the obstetrician.

When this retinitis occurs in a pregnant woman another and very important question arises: that is, whether premature labor or even abortion may not be induced if by that means it is probable that the vision, and perhaps the life, of the patient can be saved. In the space here available it is impossible to give even the principal arguments for or against such a procedure. Suffice it to say that in certain rare instances this procedure is permissible when the complaint or relapse appears in the earlier months, or when the history of former pregnancies shows a tendency to severe attacks of albuminuric retinitis.

¹ The prognosis, so far as life is concerned, is always grave in renal retinitis, cases occurring with pregnancy being excepted. The very presence of retinal lesions indicates either serious renal disease or decided general arterio-sclerosis, which is its constant associate.

The following statistics bear upon the duration of life after the development of albuminuric retinitis: In C. S. Bull's examination of 103 cases, 57, or more than 50 per cent., died within the first year; exceptionally, cases lived five or even seven years after the retinal disease had appeared. According to Possaner, patients in good social position and hygienic surroundings succumb less rapidly than those who are not so favorably placed.

E. O. Belt's statistics, gathered from various sources, are as follows: *Cases in private practice*, 155. Of these 62 per cent. died within one year, 85 per cent. in two years, and 14 per cent. lived more than two years. *Cases in hospital practice*, 75. Of these 85 per cent. died within one year, 93 per cent. within two years, and 6 per cent. lived for more than two years.

Diabetic Retinitis.—Another variety of retinitis is that known as *retinitis diabetica* or *glycosuric retinitis*. In the typical form it occurs, as a rule, only with *diabetes mellitus*, but it has also been known to be caused by *diabetes insipidus* (Bowman, Bader, Hansell). It occurs late in the disease, when other serious complications may be present—*e. g.* gangrene.

Pathology.—This is not well understood. As the vessels are probably affected primarily in all these forms of retinitis by a form of perivascularitis, this produces, directly or indirectly, most of the changes in the retina which characterize the disease. The *pathological anatomy*, as shown by the few sections thus far made, does not differ greatly from that of albuminuric retinitis. There are similar deposits of fatty degeneration, similarly situated with respect to the layers of the retina, but they are in general small, the edges are well marked, and especially is it to be noted that they are not grouped about the macula in the manner so distinctive of albuminuric retinitis. As for hemorrhages, these are small, if existing at all.¹

The secondary neuritis is either lacking or atrophy begins very early, the latter condition being apparently a feature of the pathological picture.

Symptoms.—These are similar to those of albuminuric retinitis—*viz.* imperfect central vision with contraction of the field—and the ophthalmoscopic appearances also resemble those of the latter disease very greatly; indeed, they are in many respects identical, except that the hemorrhages are less in size, and, as before remarked, there are few or none of the peculiar white radiating spots about the macula.

Diagnosis and Prognosis.—The appearances above mentioned may be sufficient to render it possible to separate this from other varieties of nephritic retinitis, irrespective of tests for sugar. The *prognosis* is grave.

Treatment.—As diabetes is counted among diseases difficult to treat successfully, reliance must be placed on proper diet. Nothing can be accomplished by local treatment. The general precautions mentioned under serous or parenchymatous retinitis should be observed.

Leukemic retinitis belongs to this group of inflammations, and is almost exclusively caused by splenic leukocythemia. Both eyes are affected. Leukocytes not only invade every portion of the retinal tissue, but opaque deposits, sometimes fringed with a reddish border, are seen extending from the macula to the equator. These have been found by Leber to consist almost entirely of lymph corpuscles.

The color of the vessels in the retina is also peculiar. The arteries are small, pink, or even yellowish, the veins large, broad, and rose-red, and the retinal tissue pale yellow. Considerable swelling of the papilla is usually present, and occasionally spots develop near the macula similar to those found in albuminuric retinitis. The symptoms are those of parenchymatous retinitis.

Diagnosis is usually easy; exceptionally, however, there is difficulty in distinguishing this disease from albuminuric retinitis, but a count of the blood-corpuscles of course determines the cause. In place of the typical appearances there may be a diffuse opacity of the retina.

There is no **treatment** except to protect the eyes and improve the general condition, if possible.

Syphilitic Chorio-retinitis.—Syphilis, as before stated, tends to show itself first in the uvea, and the retina is probably affected later; or else inflammation develops simultaneously in the retina and choroid. Indeed,

¹ According to Hirschberg, there is an exudative as well as a hemorrhagic form.

sometimes in the same person a serous retinitis may be found in one eye and a chorio-retinitis in the other, or the two diseases may exist in the same eye. It occurs from six months to two years after primary infection.

The **pathological anatomy** combines the features of perhaps the serous, or always of the parenchymatous retinitis, or of both, with those of a choroïditis.

Symptoms.—In pure chorio-retinitis of certain types the vitreous is clear, and the usual absence of marked edema renders the details of the retina distinct. In this class of cases retinal hyperemia, and often hemorrhages, are found, or a neuro-retinitis. But the most characteristic appearances are *spots of exudation* of various size and irregularly distributed. When these first appear they may be like spots of edema—whitish or elevated; later more or less complete atrophy of the retina takes place, and there results a dark or black area showing the choroid with corresponding distinctness. These spots, when small, are similar to those seen in retinitis pigmentosa. If the choroid also undergoes atrophy, white spots (the sclerotic), fringed with the black cells of the choroid, are visible. Should an artery or vein happen to cross such a spot, the vessel can be easily distinguished in the early stage, but later its outlines become indistinct; it is cut off, and atrophies there with the surrounding tissue (Plate 5, Fig. III.).

In other varieties of syphilitic chorio-retinitis in the early stages there is diffuse punctate opacity (*hyalitis punctata*) of the vitreous, especially in its posterior layers, and marked edema of the peripapillary retinal layer. Occasionally the iris and posterior layers of the cornea participate in the inflammation. Later the ophthalmoscopic changes are similar to those described in the preceding paragraph (see also page 353).

The *subjective symptoms* are analogous to those of other types of retinitis—lessening of central vision, contraction of the visual field, scotomas, diminished light-sense, and sometimes night-blindness. Photopsies, micropsia, and megalopsia are present.

Treatment.—This consists in the use of mercurials internally or by inunction, and the administration of potassium iodid. The eyes should be protected, and occasionally the artificial leech is advisable.

Hemorrhagic Retinitis is often described as a separate disease, but really it is only a form occasionally assumed by inflammations of the serous type, but most frequently by those of the parenchymatous type. For the latter reason it is mentioned in this connection. Again, variously shaped hemorrhages may appear in the retina and occasion sufficient irritation in surrounding fibers to create a retinitis.

Etiology.—The hemorrhages may be dependent upon syphilis, and in that case the walls of the vessels are altered (endarteritis, formation of thrombi), so that the hemorrhages, often small and fine, stream off, as it were, in irregular lines from the region of the nerve.

Most frequently, however, the hemorrhages are found with nephritic retinitis and with other types of retinitis dependent upon constitutional diseases. Then they are rather linear in form, but often large and irregularly distributed. Hemorrhagic retinitis may also accompany cardiac disease, general arterial sclerosis, suppressed menstruation, and the climacteric.

Hemorrhages into the retina without signs of retinitis (*apoplexy of the retina*) may be the result of senile changes in the walls of the vessels. Then the extravasations are apt to be large, irregular, and to appear even from the first, of a darker hue than that otherwise seen. The region of the macula is liable to be the seat of such extravasations as the arrangement of

PLATE 5.

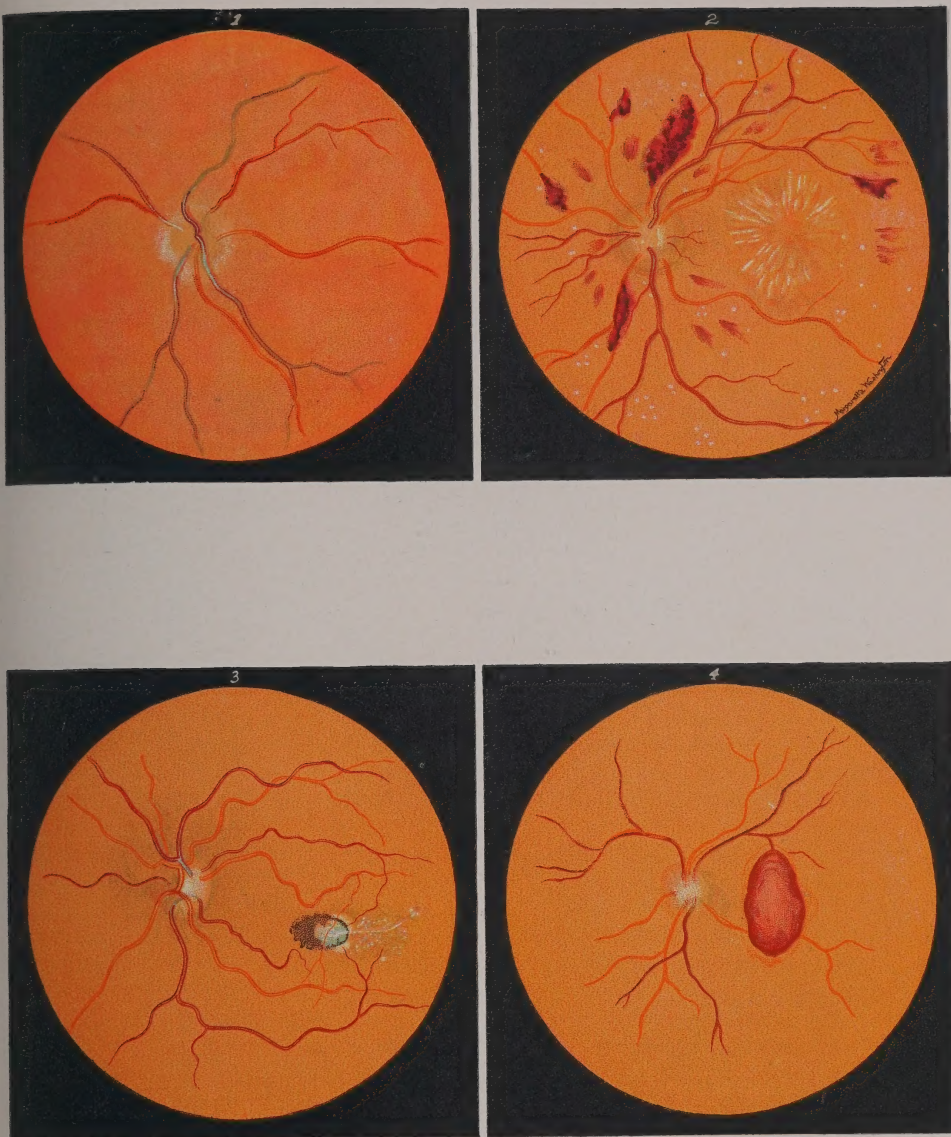


FIG. I.—Syphilitic retinitis (serous type).

FIG. II.—Albuminuric retinitis (parenchymatous type).

FIG. III.—Syphilitic chorioretinitis, late stage, following hemorrhagic retinochoroiditis (de Schweinitz).

FIG. IV.—Subhyaloid hemorrhage in the macular region.

the fibers in this locality predisposes to them. When they occur there they produce an irregular blotch or oval, usually with the longer diameter vertical, and a corresponding central scotoma. Hemorrhages of large dimensions and drop-like form usually mean an extravasation between the internal limiting membrane of the retina and the hyaloid membrane of the vitreous. Recent investigations by J. Herbert Fisher indicate that the blood is poured out from a retinal vessel—probably a minute artery—and detaches the internal limiting membrane from the retinal layers, accumulating in the space thus formed. These are the so-called *subhyaloid* hemorrhages, which occur at the yellow spot more than at other parts of the fundus (Plate 5, Fig. IV.).

Although many of the causes of retinal hemorrhage have been enumerated, a summary based upon Dimmer's classification may be added:

(a) Hemorrhages caused by changes in the composition of the blood and the tissues of the blood-vessel walls: Pyemia, septicemia, ulcerating endocarditis; diseases of the liver, spleen, kidney, and atheroma of the vessels; loss of blood (menorrhagia, hematemeses), anemia (simple and pernicious), hemophilia, purpura, and scurvy; diabetes and gout; malaria and recurrent fever.

(b) Hemorrhages caused by disturbances in the circulation: Hypertrophy of the heart and stenosis of the valves; thrombosis of the central vein of the retina and embolism of the central artery; suffocation, compression of the carotid, hemorrhages in the newly-born; and menstrual disturbances.

(c) Hemorrhages caused by sudden reduction of the intraocular tension—*e. g.* after iridectomy in glaucoma and by traumatism: Among the latter may be classed retinal hemorrhages after large cutaneous burns.

Pathology.—A *perivasculitis* or fatty degeneration of the walls of the retinal vessel, produced by the general or local disturbance, permits rupture of the artery or vein and consequent extravasation. Sometimes the hemorrhage is caused by diapedesis of blood-corpuscles. In some cases the hemorrhages are superficial, and leave the retina healthy, but in other instances atrophy results and a scotoma permanently marks the spot. Hemorrhages may take place in any layer of the retina, and by preference follow the larger blood-vessels. Sometimes they burst through the limiting membrane and pass into the vitreous. The macula, as before stated, is a favorite spot for these lesions. With the hemorrhages may be the pathological changes incident to the various types of serous and parenchymatous retinitis.

Prognosis.—At times, as already noted, superficial retinal hemorrhages are absorbed without leaving permanent scars; but if the macula is attacked, the visual disturbance is apt to be severe and lasting. Not only in this sense is the prognosis unfavorable, but the retinal hemorrhage, in most instances a sign of serious constitutional disturbance, may be the forerunner of extravasations in vital centers. Secondary changes in the optic nerve may result; sometimes glaucoma is a consequence (see page 384).

Treatment.—This should be directed toward removing the cause whenever possible to determine it. Internally, if not otherwise contraindicated, iodid of potassium may be given, ergot, small doses of pilocarpin, and bichlorid of mercury, according to various indications.

Macular retinitis is a term which, though often used for only one form of retinal inflammation occurring in the macula lutea, is really more general in its application, and may include several types of inflammatory retinal change specially located in this region. The details of these alterations are not yet clearly understood, and consequently they cannot be separated from each

other, neither by their ophthalmoscopic features nor by what we know thus far of their pathology; for it will be remembered that the appearances of the macula lutea vary considerably within normal limits.

Mention has already been made of the so-called "Gunn's dots," and these are ordinarily considered as non-pathological variations of the macula, for the reason that normal vision is found when they exist. Very nearly allied to them we have

Retinitis Punctata Albescens (*Central Punctate Retinitis*).—This affection is classed as a pathological condition, not so much because it differs materially in appearance from the Gunn's dots, but because central vision is more or less impaired. Fuchs and Liebrecht call attention to the similarity which this disease may bear to retinitis pigmentosa, in so far that it may occur in children, affecting several members of the same family, and, moreover, in children of blood-relations. Occasionally there are night-blindness and contraction of the visual field. Other cases have been reported in middle-aged patients with unchanged peripheral fields.

The most prominent feature is a group of fine, shining dots in the vicinity of the macula, often extending toward the optic nerve. Sometimes the dots are present in great numbers. A central scotoma, more or less marked, can be found, though often exact measurements are necessary to determine it; the peripheral field is unaffected. Sometimes vitreous hemorrhages occur.

Nieden and Landesberg think the spots can be made to disappear by the administration of potassium iodid and mercury, but the real effect of any treatment is uncertain.

Retinitis circinata is a term recently used by Fuchs to describe an appearance of the macula somewhat similar to that found in albuminuric retinitis. A yellowish-gray opacity is found in the macular region, surrounded at some distance by a zone of white spots or larger white patches. It is probable that this is not an inflammatory process, and that it is due to hemorrhages taking place in this locality. Some writers regard these points only as accompaniments of albuminuric retinitis (Spicer Holmes), but in a typical case recently described by Hartridge no albumin could be found.

Solar Retinitis.—Since the sight-purple in the retina was discovered by Boll, what before appeared a mysterious action of the light upon the retina is better understood. When an excessive amount of light enters the eye for a considerable time the sight-purple is destroyed to such an extent that it is not renewed either promptly or entirely. These changes in the retina when slight are not visible with the ophthalmoscope. Their effect is shown by considerable loss of central vision, though this is not necessarily complete, and by more or less limitation of the visual fields.

When, however, the crystalline lens has focussed the rays from a strong light, with the accompanying heat, upon the retina—as, for example, when an eye has been directed toward the sun—the changes produced in the yellow spot are not only more lasting, but they can often be seen with the ophthalmoscope. This has occurred particularly during observations of an eclipse of the sun, or the effect of such strong light has been shown by experiments on animals. A distinct exudation in the form of small spots of retinochoroiditis can be seen in the vicinity of the macula, and, although these appearances gradually subside, a central scotoma may persist, which indicates that the alterations in the retina were extensive.

The pathological changes are not clearly understood, but they are probably more nearly allied to the parenchymatous type of inflammation than to any other.

No treatment has been found of value in even lessening the size of the scotoma, although the protection and rest of the eye are indicated.

Symmetrical Changes at the Macula Lutea in Infancy.—This peculiar and rare condition was first described by Waren Tay, the clinical appearance being in every way similar to that which exists in cases of embolism of the central artery. The cherry-red color of the macula, in the center of a grayish-white zone about the size of the papilla, is here, as in embolism, a very marked feature of the ophthalmoscopic picture.

The condition of the patient is always peculiar, the mental and physical condition being decidedly below the normal. It is not certain what gives rise to this appearance of the retina, although the changes are probably in the deeper layers, and examinations after death show a degeneration of the spinal cord and the pyramidal cells of the cortex. The disease is always fatal, death occurring in from one to two years. In most of the cases reported the children were of Hebrew parentage.¹

Suppurative Retinitis (*Purulent Retinitis; Embolic Retinitis*).—This usually occurs in connection with severe inflammation of the choroid, but in rare instances the process can be noticed beginning in the retina before the vitreous has become cloudy.

Etiology.—It may be caused by injury (*e. g.* foreign body), but the typical forms are due to cerebro-spinal meningitis or to septic or puerperal conditions. It is also known to exist with a gouty or rheumatic diathesis. In some cases it is not easy to understand how infection occurs; but it is also beyond question that bacteria may be transported from other parts of the body into the circulation, and, finding lodgement in the retina, give rise to a purulent inflammation.

Symptoms.—It may happen that imperfect vision first attracts the attention of the patient, but ordinarily the iris or choroid has previously become involved, giving rise to ciliary injection, pain, etc., the decrease in the field of vision or in the more important central vision resulting from the general inflammation. The disease is often limited to one eye. An ophthalmoscopic examination shows changes in the retina only in the early stages. These are exudations and hemorrhages which usually extend into the vitreous, the latter soon becoming so turbid as to obscure the details of the fundus.

The diagnosis is easily made on account of the acute symptoms, or when these are absent the appearance of the fundus is sufficiently characteristic.

The prognosis is extremely unfavorable. After suppurative retinitis is well established cure is impossible. Occasionally the more acute symptoms will subside, but the retina is always left thickened, more or less detached, and shrinks finally into a band of connective tissue.

Treatment.—This is similar to that employed for an iritis or an iridochoroiditis. It is antiphlogistic. Atropin is of undoubted benefit in solutions strong enough and used often enough to keep the pupil dilated. Protection of the eye from light gives comfort, and the use of cold applications is necessary. When it is possible to reduce the temperature of the globe, it is probable that the development of the microbes is either temporarily or permanently arrested. In making cold applications to the eye they should be used only for a few minutes at a time, and care should be taken that the cloth or gutta-percha bag or coil is not kept on the globe long enough to become warm.

Attempts have been made recently to carry out the principles of anti-

¹ For a summary of the literature of this unusual disease consult an article by Koller in the *Transactions of the American Ophthalmological Society*, 1896, vol. vii., Part iii., p. 661.

sepsis in the treatment of these suppurative conditions. We know that sublimate solutions may be injected under the conjunctiva with but little inconvenience, and efforts have been made to extend the same plan of treatment to inflammation of the choroid or retina. Thus far, the method has met with indifferent success, but it is probable that *intraocular injections*, in some form, will prove of value, and, theoretically, they give promise of a brilliant future (see also page 400).

RETINAL SCLEROSES.

Thus far, the forms of retinitis which are more or less of an inflammatory nature have been considered. In addition to these, however, there are pathological changes which take place in the retina, not associated with any of the cardinal signs of inflammation, but which can be recognized by the ophthalmoscope, and which are characterized by certain symptoms. They are usually described as forms of retinitis, although it is a question whether that term should be applied to them. It is therefore better to class them together as forms of *retinal sclerosis*. In this group we have *retinitis pigmentosa* of the typical variety and of the variety with little or no pigment, and with these may also be classed the so-called *retinitis proliferans*.

Pigmented Sclerosis of the Retina (*Retinitis Pigmentosa*; *Pigmentary Degeneration of the Retina*; *Pigmented Retina and Choroiditis*.—The term *retinitis pigmentosa* is usually applied to an affection characterized by deposits of pigment in the retina of more or less peculiar form and location, the appearance being accompanied by certain definite symptoms.

As this term is ordinarily used, without qualification, it probably includes two and perhaps three diseases. The study of a large number of these cases shows that the retinas vary much from each other, and also that, while there is a certain type of symptoms to be expected, these are by no means always constantly present. As for the pigment, this not only varies in form and in the abundance with which it is found, but in some cases, where the subjective symptoms are particularly well marked, the *pigmentation is absent* entirely. In defining retinitis pigmentosa, therefore, we must consider that this is simply the name of a group of pathological processes nearly allied to each other, the exact nature of which is still unknown.

Etiology.—The etiology of the disease is also obscure. It was formerly considered that *consanguinity* was the most important element in its production, and the evidence undoubtedly shows that it is a factor in the causation of certain varieties. But it is probable that the importance of this has been overestimated, while that of hereditary syphilis and some other conditions has been overlooked. It is markedly hereditary. The affection has been found among deaf-mutes, idiots, and epileptics. The disease is either congenital or begins in childhood.

Pathology.—In considering the pathology of retinitis pigmentosa it is proper to describe the morbid process which goes on in a typical case, but it is equally necessary to remember that this process is liable to many variations. It consists, in general—(1) Of a proliferation of the connective-tissue cells which form part of the supporting structure of the retina; (2) a sclerosis in the walls of the vessels, and consequently a contraction of their diameters; (3) atrophy of the nerve-elements, with the destruction of the rods and cones; (4) usually pigmentary degeneration, taking on certain shapes which will be referred to later.

Symptoms.—The symptoms and the ophthalmoscopic appearances of retinitis pigmentosa are—

(a) *Night-blindness*.—This symptom is the one which ordinarily first attracts attention to the disease, although it is seldom noticeable until the ophthalmoscope shows changes in the retina already well advanced.

(b) *Diminution of the Central Vision*.—This is almost invariably present, although occasionally good visual acuity remains for a long time. Sometimes

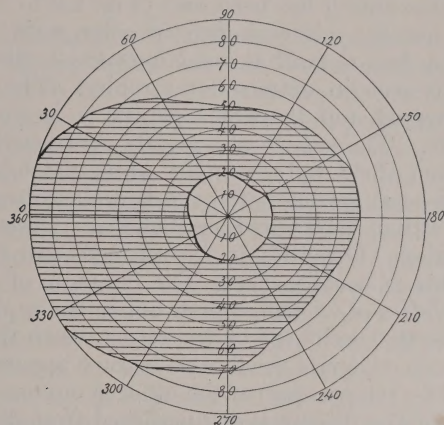


FIG. 258.—Visual field in retinitis pigmentosa.

it is associated with a true myopia, but more frequently the myopia is only apparent; for the patient approaches close to objects in order to obtain as large a retinal image as possible.

(c) *Contraction of the Visual Field*.—In typical cases this contraction is peculiar, because the concentric restriction occurs with almost perfect regu-

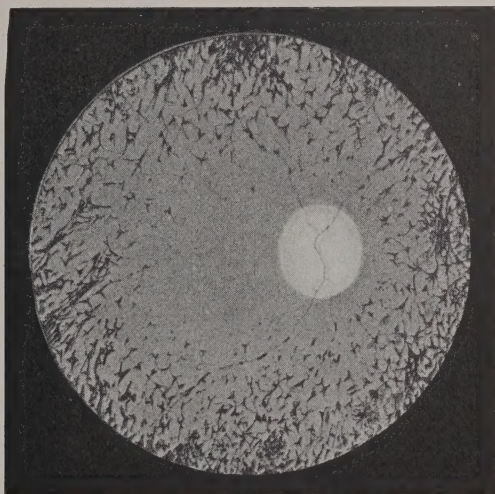


FIG. 259.—Pigmentary degeneration of the retina (Jaeger).

larity (Fig. 258). The contraction may be extreme, only a small central area of the field remaining. It is, however, liable to many variations.

(d) *Occasional Color-blindness*.—Failure to recognize red and green is the usual variety of this defect.

Ophthalmoscopic examination reveals the pigment, especially along the

lines of the vessels, and always more abundant in the periphery than near the center of the retina. The temporal side of the fundus is generally more affected than the nasal side. The pigment-masses assume an appearance resembling bone-corpuscles, and by the frequent union of their processes simulate the Haversian canals. This results in a picture so peculiar as to be easily recognized when once it has been seen (Fig. 259).

The papilla is usually yellowish-gray in color, with only slight mixing of red, and, as Leber has noticed, it sometimes has a glistening, tendon-like whiteness, such as is seen in extraocular atrophy. The lamina cribrosa is also more or less covered, and the whole papilla is, in general, smaller than is ordinarily the rule. The vessels are greatly contracted and their number is diminished. Often their walls contain white patches or are edged with white lines. The general fundus is frequently wainscotted on account of the absorption of the retinal pigmented epithelium. Posterior polar cataract may be a complication. Opacities in the vitreous are rare.

Diagnosis.—This is usually easy. The symptom of myopia might lead one to suspect this defect of vision at first, but in the typical forms it is only necessary to examine the periphery of the retina, when the peculiar star-like pigment-dots which characterize the disease become apparent. The diagnosis is further confirmed by the presence of the other symptoms detailed, especially the night-blindness. The disease is distinguished from disseminated choroiditis by the difference in the pigmentation. There is some resemblance between this affection and certain types of syphilitic retino-choroiditis; but in the latter the pigment-spots are not of characteristic form, they do not follow the blood-vessels, and vitreous opacities are usually present. Pigmentary degeneration of the retina is always bilateral.

Prognosis.—The disease invariably progresses from bad to worse. In certain cases it remains at an apparent standstill for many years, but gradually new spots appear, nearer and nearer the center of the retina and associated with a corresponding contraction in the field. The night-blindness becomes more annoying, and by the time middle life is reached or old age approaches a large proportion of the sufferers cannot find their way about without assistance.

Treatment.—Thus far, this has been equally unsuccessful in all forms. It is true that the subcutaneous injection of strychnin seems to retard the disease in some cases, and reports of the good effect of electricity, in the form of galvanism, have appeared, but, nevertheless, the treatment may be summed up by saying there is none thus far to be relied upon.

Non-pigmented Sclerosis of the Retina (*Retinitis Pigmentosa Atypica; Pigmented Retinitis without Characteristic Pigment*).—This form has been referred to when considering the typical disease, and the differences between the varieties have been noticed. While it may occur in extreme cases, as before stated, that all the subjective symptoms of retinitis pigmentosa are present, with no pigment, so also are there various degrees between these two extremes in which the ophthalmoscopic picture agrees more or less completely with what might be expected from the symptoms.

The *pathological process* in these atypical forms is not difficult to understand. The disease apparently passes through three of the stages described when considering the usual form, but the last is omitted—little or no pigmentary degeneration takes place. This is the only essential difference in the two forms, the clinical history, course, and prognosis being the same.¹

¹ Gould (*Annals of Ophthalmology*, vi., 1897) thinks these cases, which may be designated non-pigmented retinal atrophy, are more numerous than is suspected. In his paper the literature is reviewed.

Other *atypical varieties* have been described: massing of the pigment in the macular region and corresponding central scotoma; irregular distribution of the pigment, associated with clear, shining spots lying beneath the vessels; and pigment degeneration accompanied with broad peripheral zones of chorioidal atrophy. In rare instances the disease is complicated with chronic glaucoma.

Retinitis Proliferans.—This disease, like retinitis pigmentosa, is not a true inflammation of the retina, but has been considered by Manz to represent a proliferation of the connective tissue of that membrane. Indeed, there is a proliferation of Müller's fibers and a formation of new connective tissue among them. It presents itself as feathery, bluish-white expansions of tissue, often extending from the retina into the vitreous. These bands may occur in any portion of the fundus, and may follow the course of the vessels, but they are usually situated near the optic nerve, and bend about it in more or less concentric curves (Denig). New-formed blood-vessels occasionally lie above the masses. Vision is usually seriously disturbed.

The cause of the affection is not well known; syphilis and traumatism are etiological factors. Leber attributes the formation of these masses to repeated hemorrhages in the vitreous or retina. As a complicating circumstance there may be detachment of the retina. The ophthalmoscopic appearance is striking. In one case of retinitis albuminurica which the writer has observed these bands of connective tissue almost encircled the entrance of the nerve, and, curving thence toward the macula, presented a highly

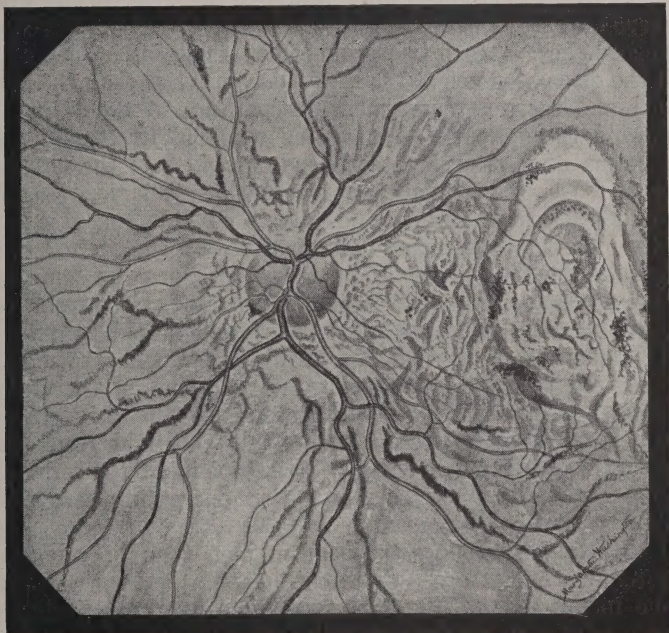


FIG. 260.—Angioid streaks in the retina (from a case under the care of Dr. de Schweinitz).

characteristic picture. As far as known, they continue unchanged in spite of all treatment.¹

Angioid Streaks in the Retina (*Retinal Pigment Striae*).—Pigment

¹ For an excellent account of retinitis proliferans consult an article by Weeks, *Trans. Amer. Ophth. Soc.*, viii., 1897, p. 158.

striae, the result of the metamorphosis of retinal hemorrhages, diffused, according to Ward Holden, in a linear manner through the deep layers of this membrane, present a striking ophthalmoscopic picture, resembling, in many respects, a system of obliterated vessels. Dark, reddish-brown, somewhat granular bands or striae, lying beneath the retinal vessels, often in the neighborhood of the disk, extend over a considerable area of the fundus. Their direct connection with hemorrhages has been demonstrated by Plange, Knapp, Holden, and de Schweinitz (Fig. 260).

Retinitis Striata.—This name was proposed by Nagel to describe an affection originally pictured by Jaeger, and characterized by light or yellowish-white stripes, often branched, lying beneath the retinal vessels. The stripes extend from the periphery toward the disk. They may be bordered by lines of pigment. The etiology of the stripes is unknown, but, like the angioid streaks, they probably have their origin in the metamorphosis of retinal hemorrhages (Holden). L. Caspar contends that all retinal striations—or, as he calls the affection, chorio-retinitis striata—represent the final stages of spontaneously cured detachments of the retina.

Detachment or Separation of the Retina (*Ablatio sive Amotio Retinae*).—This consists in a separation of the choroid from the retina, causing the latter to float in the vitreous.

Etiology.—The causes of detachment of the retina may be—

1. Stretching of the sclerotic and choroid. To this can be attributed the greatest number of cases. It occurs in high degrees of myopia (*malignant myopia*). The retina is attached only loosely to the choroid, and firmly about the optic nerve and near the ciliary processes. As the globe increases in size, the sclerotic and choroid, each being somewhat elastic, are stretched more and more, until the circumference of the retina becomes less than the space which it should fill, and there is, consequently, separation of the retina from the adjacent choroid throughout a part or the whole of its extent.

2. The retina may be pushed from the choroid into the vitreous. This may be due to (*a*) a solid substance, as a tumor or cysticercus; or (*b*) a fluid, such as an exudation from the choroid. It is possible that a serous inflammation of the choroid is, in many cases, a cause of the retinal detachment. Hemorrhages in the choroid would, of course, produce the same result, this occurring, for example, in operations for glaucoma or as the result of injury.

3. The retina may be drawn away from the choroid into the vitreous. Leber and Nordenson hold that the changes commence primarily in the vicinity of the ciliary body. A fibrillary degeneration of the vitreous commences, and as that humor shrinks the retina is gradually drawn away from the choroid. Rupture of the retina occurs, and the fluid from the vitreous passes beneath it through the opening. Detachments of the retina of a similar kind may also occur when, from injury or operation, there has been any considerable loss of the vitreous humor.

Retinal detachment is more frequent in men than in women.

Symptoms and Pathology.—The morbid conditions vary according to the causes above mentioned. Where the membrane has been pushed away and still rests on a solid base, as, for example, on a sarcoma of the choroid, it is immovable, still retains more or less of its normal color, and in parts may be found to be more vascular than usual. Ordinarily, however, there is fluid behind the retina, and it floats in a fluid vitreous. Then it has lost its usual color, and, although the vessels retain their place with regard to the retina, both may float together, moving with the motions of the globe. As the retinal vessels rise over the separated portion, they first lose the light

streak, and finally appear as dark, tortuous cords, and are apparently smaller than normal. The border of the detachment is usually sharply marked from the normal fundus, and may be accentuated by a yellowish or even pigmented line. The fluid tends to gravitate toward the lower portion of the globe, and even if the detachment, which may be *partial* or *complete*, occurs originally at the side or above, the fluid finds its way between the retina and choroid, usually to the lower portion of the eye. Sometimes the detachments are quite small, like a series of furrows; at other times an almost circular separation occurs.

Important changes also take place in the tissue of the retina itself (Klebs). As the rods and cones are macerated by the fluid in which they float they become swollen, entirely losing their original structure and consequently their function. The bearing of these facts on attempts to replace the retina is evident.

The *ophthalmoscopic picture* of extensive retinal detachment is one which cannot be mistaken for anything else. With the upright image the observer sees the grayish-white fold waving as the eye moves in various directions, and in the undulations the branches of the vessels are brought into view. The inverted image gives a general



FIG. 261.—Detachment of the retina.

The inverted image gives a general view of the condition, and often the whole or most of the detached area is brought into the field at once, showing still better the arrangement of the retinal vessels. They spread over the surface of the floating retina, sometimes appearing on the surface or again depressed beneath it, where it may be covered with a whitish cloud, probably due to local extravasation of the subretinal fluid. The other portions of the retina are often almost normal, although the papilla may appear more congested than usual (Fig. 261).

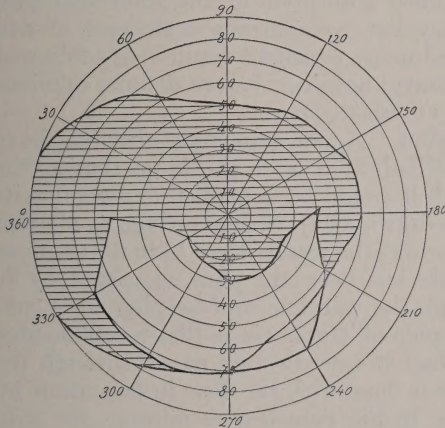


FIG. 262.—Visual field in detachment of the retina. The shading indicates where vision was lost.

corresponding loss of vision, and consequently the field assumes every possible variety of form (Fig. 262; see also Figs. 287 and 288).

2. *Metamorphopsia*.—This is not of the slight degree found in serous

Subjective Symptoms.—(1) *Imperfection of the Visual Field*.—When the detachment occurs suddenly—for example, immediately following some strain or effort of the individual—he notices what he calls a dark cloud or mist, which he may try to push away. This, of course, is the scotoma corresponding to the detachment. Wherever the detachment occurs there is corre-

retinitis, but is so great as to cause the lines of a page to be zigzag or the letters to be separated widely from each other.

3. *Dyschromatopsia* is also present, and the difficulty in recognizing colors is noted even in parts of the field apparently unaffected.

Scintillations or *phosphenes* cannot be produced by pressure on the eyeball over the separated retina.

Other alterations are not infrequent with detached retina; opacities may appear in the vitreous humor, and with these or independently of them iritis, irido-choroiditis, or cataract.

Diagnosis.—Extensive detachment, as before stated, is easily recognized, both because of the clearness of the ophthalmoscopic picture and from the subjective symptoms. If the vitreous is filled with opacities and obscures the details of the fundus, an examination of the visual field gives diagnostic proof. The difference between a retina separated by fluid or by a solid growth—*e. g.* a tumor—has been pointed out.

Course and Prognosis.—Usually the detachment extends more and more, and the portions of the retina which at first remained comparatively healthy either become detached or undergo pathological changes. In certain rare instances, however, the fluid is absorbed, and the retina is reappplied to the choroid with a corresponding improvement in the vision. It is not at all certain under what circumstances such an improvement occurs.

Treatment.—Inasmuch as many of the cases of improvement have occurred when the patient was in a recumbent position for a considerable time because of illness or for other reasons, the plan of treatment usually advised first is rest in bed for days or even weeks. This is much easier to prescribe than to accomplish. Various other plans have therefore been suggested, which have for their object—

(a) Absorption of the fluid by medication. This includes the administration of laxatives, salicylate of sodium, iodid of potassium, the hypodermic use of pilocarpin, mercurial inunctions, etc.

(b) Absorption of the fluid or coagulation by *electrolysis*. Attempts have been made by Wray and others to produce absorption of the subretinal fluid by means of the electric current. Clavelier recommends a strength of five milliampères continued one minute, and many excellent results have followed this method. More testimony is necessary, however, before definite opinions can be formed as to the relative value of this agent.

(c) Removal of the fluid by operation. Again, numerous attempts have been made to give exit to the subretinal fluid, with the hope that as the retina came in contact with the choroid it would be reappplied and resume its function. But whether that fluid was drawn away with a syringe or allowed to escape through a puncture in the sclerotic, the results have been for the most part unsatisfactory. Equally unreliable has been the plan suggested by de Wecker of passing a gold wire through the sclerotic and keeping up a constant drainage. Closely allied to this plan of treatment is that recommended long ago by von Graefe. In this method two needles are passed through the sclerotic, and, transfixing the retina as is done with the lens in laceration of the capsule, an opening is thus made in the detached membrane, the subretinal fluid being allowed to escape into the vitreous. Although this is one of the oldest methods, it still gives as good results as any other. Deutschmann has recently recommended division of the retina and vitreous humor, all strands between the retina and the shrinking vitreous being thoroughly separated. He has also assisted his laceration-operation by transplanting the vitreous humor of a rabbit into the affected eye. Finally, attempts have

been made to set up an inflammation which by exudation should bring the separated membranes together. For this purpose iodine solution has been injected beneath the retina (Schoeler's method), but the reaction is so great that the plan is only mentioned to be condemned. Charles Stedman Bull's conclusion in regard to treatment is that no better means for dealing with retinal detachment has been devised than rest on the back in bed, atropin, a bandage, and the administration of some drug which may induce absorption of the subretinal fluid.

Glioma of the Retina.—This growth is fully described in the section on Morbid Intraocular Growths, on page 494.

Subretinal Cysticercus.—This is occasionally met with, especially in Germany, but is practically unknown in America. When the entozoön is thus lodged beneath the retina, it develops there, pushes out into the vitreous, and the different stages of its growth can be easily studied with the assistance of the ophthalmoscope. These parasites have been removed with comparatively little injury to the eye or detriment to vision.

DISEASES OF THE OPTIC NERVE.

By HAROLD GIFFORD, M. D.,

OF OMAHA, NEB.

IN this section it is not proposed to discuss the affections commonly classed as amblyopias or amauroses, although in many of them the optic nerve is primarily or secondarily affected: they will be considered in another article (page 457), as will also many of the congenital peculiarities of the optic disk (pages 191-195).

Hyperemia of the Optic Nerve.—A *congestion* of the optic nerve can only be diagnosed with any approach to accuracy when the intraocular end of the papilla is involved; and the color of the normal papilla is subject to such wide variation in different individuals that a positive diagnosis of hyperemia, even where it is strongly suspected, is frequently difficult, unless the papilla has been previously examined under normal conditions or unless the nerve in question can be compared with that of the other side. It shows itself in a deepening of the normal, slightly rosy tint of the papilla, the larger vessels remaining unchanged, or, at most, the veins showing enlargement. Its diagnosis is chiefly of value as a premonition of approaching inflammation or of inflammation already existing farther back in the nerve. It also occurs in many cases of choroiditis or with inflammation or irritation of the iris, cornea, or ciliary body. Where, in addition to a decided congestion, the outlines of the papilla become at all indistinct, it is preferable to speak of slight or incipient optic neuritis.

Optic Neuritis.—Where an inflammation of the optic nerve is plainly revealed by the ophthalmoscope, it is commonly called *papillitis*, although in many cases the retro-ocular portion of the nerve is also involved, sometimes very extensively.

Where from the severity of the disturbance of vision in comparison with the negative or slightly pronounced character of the ophthalmoscopic symptoms an inflammation of the nerves between the eye and the chiasm is diagnosed, the condition is termed *retro-bulbar neuritis*.

Papillitis, or Intraocular Optic Neuritis.—Soon after the invention of the ophthalmoscope permitted intraocular lesions to be studied during life, v. Graefe was led to divide inflammations of the optic disk into two classes: papillitis from stasis (*Stauungspapille*), commonly called *choked disk*, which he supposed to be due to edema and hyperemia of the disk from increased intracranial pressure; and *descending neuritis*, sometimes known as *simple optic neuritis*, in which he believed that the inflammation spread down the nerve-trunk from the intracranial lesion. The experience of subsequent years has shown that the lines between these two forms cannot be drawn sharply, either from a pathological or an etiological standpoint, although for practical purposes the distinction is a useful one.

Objective Symptoms.—In its pronounced form choked disk is charac-

PLATE 6.

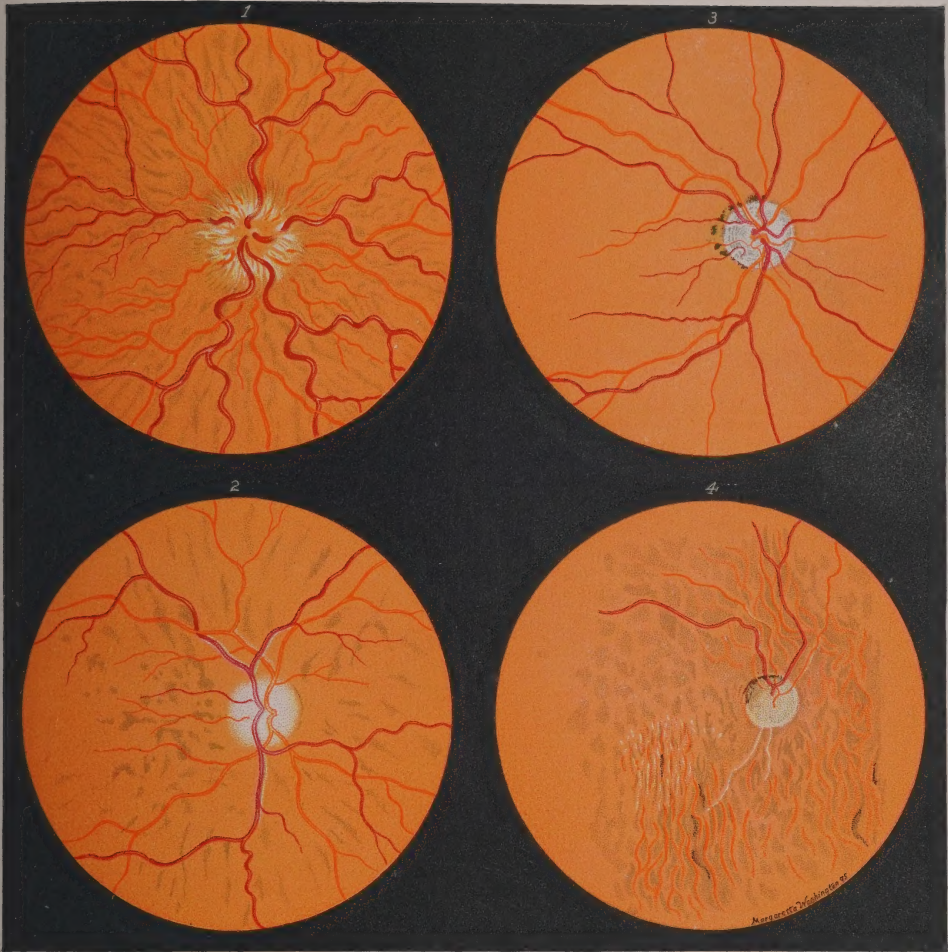


FIG. I.—Papillitis (choked disk) (modified from Haab).

FIG. II.—Post-papillitic atrophy of the optic disk (modified from Haab).

FIG. III.—Simple or gray atrophy of optic disk (from a case of locomotor ataxia).

FIG. IV.—Embolic atrophy of the optic disk, with secondary retinochoroidal atrophic changes (de Schweinitz).

terized by entire obliteration of the outlines of the papilla, an elevated mass of tissue, marked on the surface by radiating striæ which fade off gradually into the surrounding retina, taking its place; near the center of this the larger retinal vessels appear, the veins being generally large and tortuous, while the arteries often are apparently reduced in size. On and close beneath the surface of the elevation may generally be seen numerous enlarged capillary vessels, while on its borders and in the surrounding retina small patches of whitish *exudate* and *hemorrhages*, often flame-shaped, are not uncommon. Very rarely *pulsation of the retinal arteries* has been seen (Plate 6, Fig. I.).

When the hemorrhages and patches of exudate are large and numerous in proportion to the elevation of the disk, the condition is more often termed *neuro-retinitis*, and in such cases opacities may develop in the posterior portion of the vitreous, sometimes with *newly-formed blood-vessels* leading out to them. The height of the elevation, measured with the ophthalmoscope, varies from 1 D. to 6 D. If it is less than this, the term choked disk hardly applies, and the condition verges into that of *simple papillitis*, where, with less complete obliteration of the borders of the papilla, with much less strongly marked striation, hemorrhages and exudate may occur even more extensively than in cases of pronounced choked disk.

In some cases the condition of choked disk may persist with little change for months or even for a year or more, but sooner or later, if the patient lives, the elevation recedes; the striation of the tissue becomes less marked; the hemorrhages and exudate, if any existed, are absorbed; and the outlines of the papilla begin to show dimly. With the continuation of this retrogressive process the picture generally changes to that of *neuritic atrophy*, to be described later on. In some cases, however, where the inflammation has not been very severe nor prolonged, the nerve may gradually assume an almost normal aspect.

Subjective Symptoms.—While, in general, it may be said that in cases of choked disk the disturbance of vision increases with the evidence of stasis in the papilla, this rule is subject to great exceptions. The vision of eyes presenting the same ophthalmoscopic picture is found to vary between the normal and complete blindness; occasionally marked choked disk persists for many months without any perceptible impairment of sight. This fact and the fact that the sight may be subject to sudden changes without any corresponding difference in the ophthalmoscopic picture suggest that much of the disturbance of vision may be due to accompanying *retro-bulbar* or *intra-cranial* lesions. The occurrence of normal vision with marked choked disk, where the development of the papillitis is not too sudden, may be explained, as Leber suggests, on the ground that the nerve-fibers may accustom themselves to the changed position and increased pressure without impairment of function.

Where, as is common, the sight is seriously interfered with in the course of the papillitis, there is generally a gradual reduction of the central acuity, sometimes with a central *scotoma*, more often with a *contraction of the field* at the periphery, and frequently more marked at the nasal side; but the mode in which the field of vision is interfered with is subject to all sorts of variations. The *color-sense* necessarily suffers greatly in the severe cases, but if the amblyopia is not extreme it may be very little affected. Sometimes with marked peripheric contraction of the field for white the color-limits in the remaining portion of the field may be normal. Disturbances of the normal relations of the color-limits may be observed—*e. g.* red in certain areas may be seen farther toward the periphery than blue.

Some patients complain of flashes of light and other subjective phenomena indicating irritation of the optic-nerve fibers.

With the subsidence of the ophthalmoscopic symptoms an improvement of vision generally sets in, which will be considered more fully when treating of the Prognosis.

Pathology.—Pathologically, the distinction between *choked disk* and *descending* or simple *neuritis* is found to be entirely arbitrary. In some cases in which, during life, there was a choked disk, *post-mortem* examination reveals that the inflammation is limited almost entirely to the intraocular part of the nerve, with a distention of the intervaginal space by serous fluid as almost the only retro-ocular symptom. In others there is marked, sometimes purulent, inflammation in the intervaginal space and the nerve-sheaths, with very little affection of the nerve; while in still others the nerve-trunk is the seat of an intense interstitial inflammation, and the intervaginal space and outer sheath are normal. Conversely, the ophthalmoscopic picture of simple neuritis or neuro-retinitis may coexist with inflammation of the nerve-trunk or with a normal nerve-trunk and extensive *hydrops* or inflammation in the intervaginal space and its walls.

Microscopically, a choked disk in the early stages shows severe venous hyperemia, with some edema, although on account of post-mortem changes

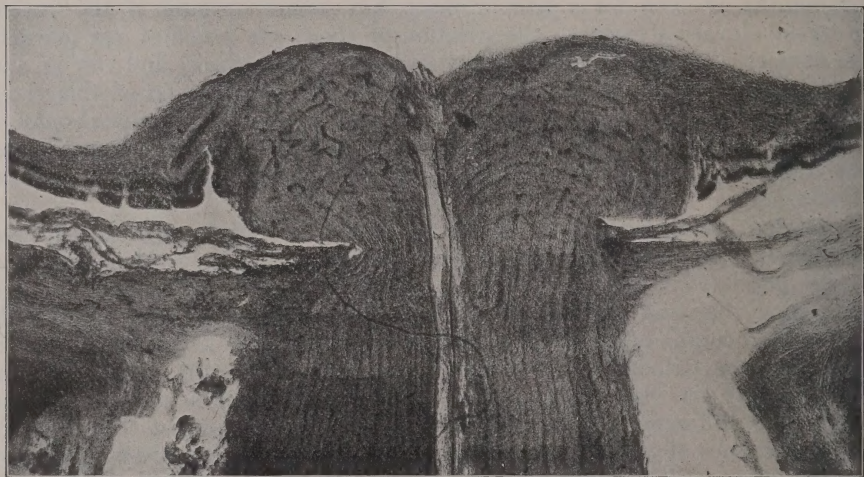


FIG. 263.—From a photo-micrograph by Dr. James Wallace of a section of a choked disk prepared by Dr. William Thomson.

the latter lesion is less marked than would be expected from the ophthalmoscopic appearance; and a marked swelling of the nerve-fibers. Later, the tissues become infiltrated with leukocytes, and accumulations of these at points corresponding to the areas of whitish exudate seen during life are found to have undergone granular or fatty degeneration. Fresh hemorrhages are, of course, visible as such, while older ones are suggested by patches of pigment. Still later, the formation of new connective tissue becomes apparent, especially along the blood-vessels, the walls of which are often much thickened. The nerve-fibers atrophy to a greater or less extent, their place being taken by granules and minute fat-like globules, which in their turn become absorbed (Fig. 263).

The changes in the retro-ocular portion of the nerve-trunk are mainly those of an *interstitial neuritis*, the septa of connective tissue being infiltrated

with leukocytes and, later, thickened from new formation of connective tissue. From the resulting pressure, and perhaps from the direct influence of the *ptomaines*, the nerve-fibers, if the process continues long, undergo degenerative changes and atrophy. The degenerative changes in the nerve-fibers, sometimes described as *medullary neuritis*, are probably, as Alt suggests, merely secondary to interstitial inflammation or to degeneration elsewhere.

Where, with the main lesion in the nerve-head, the signs of inflammation extend into the nerve-trunk for a short distance toward the brain, the condition is termed *ascending neuritis*. In such cases edema of the nerve-trunk has been frequently found. Besides the hydrops of the intervaginal space, which is so common, *optic perineuritis* often occurs in the form of more or less inflammation of the opposing surfaces of the pial and dural sheaths and of the arachnoidal framework between them. This may be slight, or so severe as eventually to obliterate the intervaginal space with a mass of new-formed connective tissue.

Etiology.—The most frequent cause of typical choked disk is the development of an *intracranial tumor*, some observers stating that it occurs in 95 per cent. of all cases of such tumors. The nature of the tumor seems to be of very little importance: it may occur with any of the neoplasms, whether of the brain-substance, of the meninges, or of the bony walls, or with gum-mata, tubercles, cysts (whether of entozoic or other origin), abscesses, or aneurysms. Tumors of the cerebellum are especially apt to produce it.

The method in which brain-tumors cause optic neuritis is a matter still in dispute. Von Graefe supposed that, owing to the increase of intracranial pressure, an abnormal amount of fluid was forced into the intervaginal space, and produced a stasis in the papilla which tended to become exaggerated on account of the unyielding nature of the walls of the channels through the lamina cribrosa. These acted, it was supposed, like the abdominal rings in a case of strangulated hernia, the pressure, naturally, having a greater effect upon the outflow through the yielding veins than upon the inflow through the stiffer-walled arteries. This theory received considerable support from the observation of Manz and others, that in many cases of brain-tumor there actually existed a distention of the intervaginal space with cerebro-spinal fluid.

The other most widely accepted theory is that of Leber and Deutschmann, who hold that the optic neuritis in these cases is not merely a stasis, but is an active inflammation caused by the passage of irritating substances, produced either directly or indirectly by the tumor, from the cranial cavity down to the nerve-head. In favor of this view it may be said that, as a rule, a certain amount of meningitis can be demonstrated in the neighborhood of most brain-tumors, and that in many cases no hydrops of the intervaginal space can be found, but, on the contrary, a normal intervaginal space with marked interstitial inflammation of the nerve-trunk. The alleged production of the symptoms of choked disk in animals by injections into the cranial cavity or into the vaginal space are not admitted as evidence by the supporters of the inflammation-theory, on the ground that higher pressures were used than probably ever occur in the human being. The objection that typical choked disk is seldom observed in cases of acute meningitis, is met by the suggestion that the slight neuritis which is often observed does occasionally develop into a choked disk if the patient lives long enough.

A careful review of all the available facts leads one to believe that while, in certain cases, the element of intracranial and intervaginal pressure plays an important part in the production of choked disk, in the majority of cases the latter depends upon an active inflammation.

In addition, there should be mentioned the theory of Parinaud, who holds that choked disk results from an extension, through the trunk of the optic nerve to the papilla, of the interstitial edema of the brain-tissue which is so commonly found in intracranial troubles. This edema of the nerve-trunk is also recognized by Ulrich, but he holds that its effects upon the papilla are produced not directly, but by compressing the central retinal vein.

The importance of optic neuritis as a symptom of brain-tumor can be appreciated from the fact that, aside from its frequency, it is sometimes the first symptom to attract the notice of the patient; in fact, the progress of the tumor may be so slow that, as in a case reported by Leber, a slight optic neuritis may even pass over into atrophy without the knowledge of the patient, years before death occurs. The occurrence of a double choked disk, then, without other grounds for its explanation, is always sufficient reason for a strong suspicion of brain-tumor. As a source of error in such cases, may be mentioned the unique case of Krohn, in which a double optic neuritis was caused by a small metastatic tumor from an ovarian carcinoma developing in the optic nerve immediately behind each globe.

In rare cases the optic neuritis accompanying brain-tumor is *one-sided*, and may even occur on the side opposite to the growth. This is explained by the supporters of the pressure theory of choked disk on the ground of a localized meningitis or hemorrhage.

Of extreme rarity also is the occurrence, in a case of suspected brain-tumor, of a *second attack* of *papillitis* some time after the first has subsided. In the case of de Schweinitz and A. Thomson the neuritis, headache, and epilepsy disappeared after a simple trephining, but all returned at the expiration of a year.

With reference to the diagnosis of brain-tumor, it should not be forgotten that, occasionally, a tumor may cause a neuro-retinitis precisely like that generally considered diagnostic of *albuminuria*.

Discarding the distinction between choked disk and simple or descending neuritis, it may be said that all tumors or inflammations within the cranial or orbital cavities may cause a papillitis; this naturally includes all the varieties of *meningitis* and *infectious thrombosis of the brain-sinuses*.

Optic neuritis has also been observed in the greatest variety of *infectious* and other *general diseases*. It has been most commonly noticed in the course of measles, typhoid fever, and "la grippe," but it has also been mentioned in connection with scarlatina, variola, malaria, whooping-cough, beri-beri, pellagra, typhus, typhoid pneumonia, rheumatism, diphtheria, and myxedema. In some of these cases the neuritis is undoubtedly secondary to a nephritis; in others, to a meningitis; but there is no reason for supposing that some of them may not indicate an actual infection of the trunk or intervaginal space of the nerve, while still others may result simply from the general toxemia. Neuritis also occurs with various disorders of *menstruation*, generally with a sudden checking of the flow, and with *premature menopause* and atrophy of the uterus. The fact that in adults, as well as children, *hydrocephalus internus* may cause double-sided neuritis is of importance, because, on account of the unyielding character of the skull, the diagnosis is much more difficult than in children, and the neuritis might be thought to confirm an erroneous diagnosis of brain-tumor.

Optic neuritis has also been observed in various marked *deformities of the skull*, particularly in the high and narrow variety known by the Germans as "*Thurmschädel*" (tower- or steeple-skull). A post-mortem examination in one such case (Michel) showed signs of pachymeningitis, with marked hyper-

ostosis of the skull-bones, both optic foramina being decidedly narrowed. With multiple foci of *cerebral softening* the nerve has, in the early stages, been found to be inflamed, atrophy setting in later, though it seems probable that the hemorrhagic meningitis which often accompanies such cases is the more direct cause of the inflammation of the nerve.

With various other brain and *spinal diseases*, to be considered more fully in connection with atrophy of the nerve, a slight optic neuritis has been observed as a forerunner of the atrophy.

Syphilis may cause optic neuritis, either by attacking the nerve directly or by producing a gumma in the cranial cavity.

Whether the cases of neuritis which have been observed in the *puerperal state* have been due to a general infection, or whether they are more akin to the cases which Valude and Bull have reported, in which the optic nerve has been attacked in several successive pregnancies, apparently without any kidney complications, is uncertain. It is possible, also, that some of the cases which have been described as neuritis during *lactation* may belong here, although others are more probably akin to the neuritis which has been observed in the course of *chlorosis*. The anemia produced by the too abundant or too long-continued lactation, as well as that occurring in the chlorosis, produces neuritis, probably through hemorrhages resulting from malnutrition-changes in the walls of the blood-vessels. In other cases the affection of the optic nerve has seemed to be due to a sudden checking of the flow of milk.

The neuritis which sometimes follows *severe hemorrhages* is also probably due to alterations in the blood-vessel walls, the malnutrition caused by the extreme anemia so weakening the coats of the vessels that, when the blood-current begins to resume its normal force, transudations and hemorrhages occur which may either give rise to the picture of optic neuritis directly, or possibly indirectly, through pressure in the intervaginal space. A striking case of this character is that reported by Gessner, in which three weeks after a severe post-partum hemorrhage the vision suddenly became affected, the difficulty progressing within three days to complete blindness; the ophthalmoscope revealed a marked choked disk in each eye. This was immediately followed by the onset of an *ascending myelitis*, which caused the death of the patient at the end of two weeks.

A cause of neuritis which has been insisted upon by Panas is *gonorrhea*, though, in the case which he reports, the connection between the urethral affection and the neuritis is less obvious than in the more recent case of Campbell-Highet. In Panas's case one eye remained blind, the other being scarcely affected, while in Campbell-Highet's case the affection was one-sided and ended in complete recovery.

In treating of the effects of *nephritis*¹ upon the eye the main stress is usually laid upon the retinitis, though, so far as the functional disturbance is concerned, the optic neuritis is probably of greater importance. The retinitis is much more apt to clear up without leaving permanent damage, if the nephritis is of the curable variety, than is the affection of the nerve. The writer has a case on hand at present in which the retinitis has been cured for months, while the nerves are still far from normal. It should be remembered, too, that nephritis may reveal itself in the eye by the typical appearance of choked disk without any of the ordinary retinitis albuminurica. It is probable also that nephritis may cause serious damage to the optic-nerve trunk through retro-bulbar hemorrhages or localized areas of edema.

¹ The neuro-retinitis which occurs in lead-poisoning is generally secondary to the lead-nephritis, though sometimes the nerve may be affected directly in this as in other sorts of poisoning.

Since *intranasal cauterization* occasionally causes meningitis, it can easily be understood how it might also cause an optic neuritis, although in the case of Alt, in which one-sided papillitis developed immediately after cauterization of one of the turbinated bones on the same side, there were no decided symptoms of meningitis, and a nearly complete recovery followed rapidly on the subsidence of the intranasal irritation.

While *acromegaly* generally causes atrophy by pressure of the enlarged pituitary body on the chiasma, it not infrequently produces optic neuritis.

The cases of double optic neuritis which develop immediately after *sunstroke* or some *violent physical exertion* are probably due to hemorrhage or effusion within the cranial cavity, with secondary meningitis. In the only case following sunstroke which the writer has seen dementia and permanent blindness resulted. In a case following a violent run to catch a car useful sight was recovered after complete blindness had persisted for months.

Carious teeth or the reaction following their extraction may cause optic neuritis, apparently through the extension of a phlebitis directly to the orbit or through the intervention of an abscess of the antrum of Highmore with secondary orbital cellulitis.

After taking account of all the known causes, there remain quite a number of cases of optic neuritis for which no probable cause can be ascertained. These cases, in the experience of the writer, are frequently *monocular* and may be slight or severe, but they offer, on the whole, a relatively good prognosis.

Diagnosis.—The diagnosis of intraocular optic neuritis rarely offers any difficulty where the media are clear; the only conditions which are liable to be mistaken for neuritis are hyaline bodies in the papilla (to be discussed later) and an obscuration of the borders of the disk by opaque nerve-fibers. Where these opaque fibers occur in solid patches they can hardly be mistaken for anything else, but where they occur sparingly mixed in with the ordinary sheathless fibers, the margin of the disk may be more or less completely obscured by a grayish striation, reminding one strongly of the appearance in a mild case of choked disk.¹ A careful examination of the direct image, showing the absence of enlarged capillaries and other signs of stasis, will almost invariably clear up the diagnosis, but where there is some functional disturbance this condition may occasionally cause some uneasiness, as is shown by a case seen by the writer in which an ophthalmologist of the utmost ability diagnosed neuritis; subsequent continued observation showed that the cause of the blurring of part of the disk-margin was due to this admixture of opaque fibers. If the media are not perfectly clear, it is not always possible to determine whether the cause of the blurred image of the disk is due entirely to the interference with the passage of the light. If the opacities in the media are easily detected, the observer will naturally be on his guard, but where the want of transparency is due to the extremely fine opacities which sometimes exist in the vitreous or upon the posterior surface of the lens, the beginner might easily overlook these, and, thinking the media clear, diagnose an incipient neuritis with blurred disk-margins. To avoid this error one should, of course, examine the cornea, lens, and anterior vitreous with a strong convex lens.

Prognosis.—This must always be guarded. There is absolutely no means of determining whether a case of neuritis, seen for the first time, will result in total blindness or in the restoration of normal vision. Where the ocular disturbance depends upon some general affection the prognosis will

¹ Cases, probably of this nature, have been described as *false* or *spurious optic neuritis*.

depend upon the course taken by the latter: aside from the nature of the ultimate cause, the rule, as would naturally be expected, is that the greater the severity of the neuritis the greater the permanent damage to the sight, through the destruction of nerve-fibers, during the neuritis or in the course of the subsequent atrophy. In general, it may be said that where the ultimate cause of the disease is not of a hopeless character the prognosis is relatively good, since useful central vision is often left, though frequently with more or less contracted fields. The writer has certainly seen and committed more errors on the unfavorable than on the favorable side of the question. Where the course of the neuritis has been rapid the vision is apt to improve with the subsidence of the ophthalmoscopic symptoms, sometimes becoming worse again when the secondary atrophy sets in. On the other hand, where the neuritis has run a long chronic course, with only a moderate amblyopia, the vision sometimes fails rapidly and continues to fail throughout the retrogressive stage. In still a third class of cases the writer has seen useful vision restored at the retrogression of a marked papillitis which had persisted with absolute blindness for several months.

Treatment.—If the disease depend upon some general affection, the latter, of course, should first engage the attention of the physician, and the ocular condition may need no special treatment. Occasionally, however, it does, on account of the danger that while waiting for remedies to act upon the general condition permanent damage might be done to the sight, which could perhaps be prevented by a more vigorous line of treatment. Where the optic-nerve lesion is not secondary to any other affection which requires attention, it is very uncertain what line of treatment will have most influence upon it. Full doses of salicylate of sodium or of iodid of potassium, mercurial inunctions (even in non-specific cases), and the various forms of sweat-cures have all been used with apparently good results in some cases, while in others they have had no influence. In very critical cases the writer has used the iodid of potassium, inunctions, and pilocarpin at the same time, with apparently good results. Those who use mercury in non-specific cases generally recommend it, in particular, where there is evidence of active inflammation, while others use large doses of iodid in precisely similar cases. A sweat-cure, either with pilocarpin, salicylate of sodium, or the Turkish bath, is always in order. Where neither pilocarpin nor the salicylate, nor a combination of the two, can be borne in a sufficiently large dose to produce free diaphoresis once a day, and circumstances do not permit visits to a Turkish bath-house, the writer has found an improvised hot-air bath, obtained by the use of a small lamp and enough rubber sheeting to cover two chairs, to be of great service, particularly in cases of nephritic origin. If mercury is used at the start in preference to the iodid, it may be exchanged for the latter when signs of mercurialization appear; and its use, in any case, should be continued off and on for months unless a complete cure should result sooner. Cupping or leeching the temples is still recommended by many and can do no harm. It is more than doubtful whether the use of setons in the temple or at the nape of the neck is even justifiable. In syphilitic lesions of the optic nerve, rapidly produced mercurialization by inunctions, repeated at intervals, with iodid in full doses during the intervals, gives the best results.

In the way of direct operative interference de Wecker's plan of incising the dural sheath may be mentioned as a curiosity.¹ From the standpoint of

¹ Von Hoffman in one case evacuated pus from the intervaginal space. The operation did not prevent atrophy.

v. Graefe the proposal was a rational one, but the difficulties and dangers attending the operation have prevented its general adoption. More promising is the performance of trephining the skull, with or without the puncture of a lateral ventricle, where the neuritis is due to hydrocephalus internus, whether the latter be caused by brain-tumor or by something else. Several cases of this kind are on record in which the operation has been followed by a marked improvement of the neuritis and of the vision. This treatment is of course resorted to only where the intracranial disease itself is of a very serious nature; and the relief and any improvement of vision obtained are not likely to be permanent, since the primary disease is generally incurable.

Where the neuritis depends upon the pressure of a brain-tumor which can be removed completely, it may be permanently cured. Operative treatment may also cure a neuritis caused by an orbital tumor or by an inflammation or tumor of one of the accessory sinuses, or by any of the intracranial inflammations of otitic origin.

Acute or Fulminant Retro-bulbar Neuritis.—In the cases which v. Graefe originally classified here, blindness came on suddenly, the ophthalmoscope showing very small but still permeable retinal arteries and a very slight blurring of the edges of the disk. He considered that the symptoms were due to a compression of the central vessels by the products of a retro-bulbar neuritis. Some of his cases would now probably be called simply thrombosis of the central artery.

Etiology.—In quite a number of cases severe exposure or rheumatism can be adduced as a cause of this affection; it has also followed infectious diseases, of which influenza seems particularly liable to produce it. In many cases no sufficient cause can be discovered. The disease seems to be one of the forms of multiple neuritis which may be produced by any of the toxins circulating in the blood. *Acute or subacute myelitis* is frequently accompanied by this same set of eye-symptoms, excepting that the ophthalmoscope shows a marked neuritis or a choked disk; hence it is manifestly arbitrary to make a separate group of the cases in which the neuritis happens not to reach as far toward the distal end of the nerve as it does in others.

Symptoms.—At the present day the diagnosis of acute retro-bulbar neuritis is made when one meets the following complex of symptoms: Pain back of the eye, spontaneous or upon movement of or pressure on the eyeball; obscuration of vision, progressing in the course of from one to eight days to complete or nearly complete blindness; ophthalmoscopically, a normal disk or a hyperemic nerve-head with or without slight haziness of the surrounding retina; and, rarely, minute retinal hemorrhages and small grayish or yellowish spots in the neighborhood of the macula. With these symptoms are not unfrequently associated others pointing to acute myelitis or, more rarely, multiple neuritis. Death may occur within a few weeks of the onset of the disease.

Before amaurosis becomes absolute the sight may undergo sudden variations; thereafter it gradually improves slowly until, occasionally, normal vision is restored. More frequently the restoration stops short of this, and a certain degree of amblyopia remains either with a contracted field or with central scotoma, or with both. The color-sense is apt to be severely affected throughout the disease. As the process begins to decline more or less complete atrophy of the disk occurs.

The affection may be one-sided, or both nerves may be affected simultaneously, or there may be a very short interval between the attacks. In other

cases recurring attacks at intervals of a month or more affect both nerves or one nerve after the other.

Pathology.—What is known of the pathology of this affection we owe almost entirely to Achard and Guinon, Elschnig, Dreschfeld, and Katz, who have found interstitial neuritis generally throughout the whole diameter of the nerve, in some cases from the chiasma to the globe, with secondary degeneration of the nerve-fibers. Whether similar symptoms may not be produced by a perineuritis or by a periostitis in the optic canal remains to be seen. As Elschnig suggests, the latter condition might cause a compression of the ophthalmic artery, and thus produce the ophthalmoscopic picture seen by v. Graefe. It is probable that still other cases are caused by a pachymeningitis spreading into the optic canals. Thus, in a case observed by the writer the patient had several attacks of complete double-sided blindness at intervals of several months; the attacks were preceded for some time by severe headache, and after the last attack an almost constant headache persisted for nearly a year.

Prognosis.—The prognosis is favorable so far as the regaining of useful sight is concerned, complete blindness remaining very rarely, if ever. Serious permanent visual disturbances, however, are not unusual, and are apt to be worse in those cases in which the ophthalmoscopic symptoms of neuritis have been most pronounced.

Treatment.—The same treatment as that recommended for optic neuritis in general should be ordered, especial stress being laid upon large doses of salicylate of sodium where the affection seems to be of rheumatic origin.

Chronic Retro-bulbar Neuritis.—Perhaps some of the cases mentioned in the preceding section, where a succession of acute attacks occur, might properly be considered chronic. Besides these there are others which pursue a slower course, the loss of vision progressing during several weeks or months in the form of a *central scotoma*, at first relative (*i. e.* some or all colors being mistaken within its borders). Some cases are complicated by a peripheral contraction of the field, which in rare, severe instances may meet the central scotoma so as to produce absolute blindness. The ophthalmoscope in the early stages may show nothing abnormal, or there may be congestion of the disk and slight haziness of the surrounding retina. Later, if the disease continues long, atrophy of the outer quadrant or half of the optic disk becomes evident, and occasionally the whole disk appears atrophic, even where the defect of vision is limited to a *central scotoma*.

Etiology.—Some of these cases can be attributed to rheumatism or exposure; in others chronic meningitis or periostitis in the optic canal may be assumed; and sometimes no probable cause can be assigned. But the great majority are caused by systemic poisoning with alcohol, tobacco, lead, or some other drug or substance taken into or developed within the body, and they have been so long classified as *toxic amblyopias* that they and their pathology will be considered fully in another article (see page 459).

A special form of retro-bulbar neuritis, commonly known as *hereditary nerve-atrophy*, is one which appears in members of the same family, generally between the ages of eighteen and twenty-two, though it may occur as early as five years or as late as forty-three. In the great majority of cases males alone are attacked, and, where the disease can be traced through several generations, it is generally transmitted by the unaffected females to their male offspring.

The course and ophthalmoscopic symptoms of the affection are those of a subacute retro-bulbar neuritis, a permanent simple scotoma with more or less

amblyopia almost always remaining, total blindness persisting very rarely. The cause of the affection has only been surmised.¹

Prognosis.—In the cases caused by systemic poisoning the prognosis for the restoration of normal vision is good if the poisoning can be stopped before actual destruction of nerve-tissue has taken place, and even where the ophthalmoscopic appearance and the duration of the affection would render complete recovery improbable, normal vision is restored in some cases.

In the non-toxic cases the prognosis is not so good, owing to the doubt which generally exists as to the cause, and as to the possibility of any line of treatment really having much influence upon the course of the disease. Permanent blindness rarely results, however, and the more rapid the course of the affection and the less pronounced the ophthalmoscopic symptoms, the better the result to be expected.

Treatment.—In the toxic cases the poisoning should be stopped, while in the others the same treatment recommended for the acute cases is in order.

Atrophy of the Optic Nerve.—By atrophy of the optic nerve is meant, strictly speaking, the disappearance of a larger or smaller proportion of the nerve-fibers, but practically the term is also used for any condition in which the ophthalmoscope shows the papilla or a considerable part of it to have permanently lost its normal tinge of pink, through the disappearance of a large proportion of the normal number of capillary blood-vessels or through the formation of new connective tissue within it.

If the reduction of blood-supply be only temporary, we may speak of *anemia of the disk*, or, if it occurs suddenly and is very extreme, of *ischemia of the disk*.

Varieties and Objective Symptoms of Optic-nerve Atrophy.—If the atrophy develop without previous inflammation of the nerve, it is called *simple* or *primary* or *non-inflammatory* atrophy.²

The distinctions made by many writers between *white* and *gray* atrophy and between *cerebral* and *spinal* atrophy are not well grounded, for the first refers merely to an appearance of the nerve which may be transient, a white atrophy sometimes passing over into a gray, and either being sometimes produced by the same cause; while the second depends upon the assumption that the optic-nerve atrophy in a large class of patients is the consequence of spinal disease, whereas it is now known that the optic atrophy, while dependent upon the same cause as the spinal disease, originates quite independently of it and often antedates it.

In simple atrophy the nerve is white, bluish white, or grayish white, with clear-cut edges, and frequently with a shallow excavation which may

¹ Of interest is the apparent connection with the brunette type. Thomson reported a family in which the blue-eyed children retained normal sight, while the dark-eyed ones were affected with atrophy of the optic nerve. This recalls the observation from the pre-ophthalmoscopic times of Travers, who says (*Synopsis of Diseases of the Eye*, London, 1821, p. 302): "I know a family of several well-formed children, three of whom have dark hair and eyes, the others light hair and blue eyes. Toward puberty all the dark-haired children have become epileptics and gradually lost their sight, the eyes, except in the expansion and immobility of the pupils, retaining every appearance of health."

² Much confusion exists in the terminology of optic-nerve atrophy. By the term *simple* some authors designate those cases for which no probable cause can be assigned. Others separate from simple atrophy, as used in this work, the cases in which the atrophy depends upon some definite retro-bulbar lesion, classifying these as *descending* atrophy. In general, by *descending* atrophy is meant simply that the lesion is back of the eye, so that it must descend before becoming evident in the disk, while in *ascending* atrophy the primary lesion is more peripheral and leads to a degeneration passing up to the higher centers. The term *cerebral* is sometimes applied to the cases depending on an intracranial lesion. *Progressive* atrophy simply means that the process progresses steadily.

extend to the temporal margin, but which is generally not sharply defined. The vessels often show some reduction in size, but this is seldom extreme, as it is in some other forms of atrophy. In some cases the lamina cribrosa shows plainly, in others it does not (Plate 6, Fig. III.).

The atrophy occurring after inflammation of the intraocular end of the nerve (*neuritic or post-neuritic atrophy*) differs from the preceding form by more or less marked narrowing of the arteries, by the presence of white streaks of connective tissue along the large blood-vessels, by more or less irregularity or obscuration of the margin of the disk, and by a chalky, opaque whiteness in contradistinction to the clear somewhat translucent appearance which is seen in most cases of simple atrophy (Plate 6, Fig. II.). With the lapse of time, however, these differences are apt to become much less pronounced, and sometimes they disappear altogether. In some cases of neuritic atrophy a network of newly-formed blood-vessels is left upon the disk; and this symptom, when it occurs, is, in the writer's experience, the most permanent of all the signs of a previous neuritis. A moment's consideration will show that some cases of atrophy secondary to a neuritis will be classed, from the ophthalmoscopic appearances, with simple atrophy—namely, those due to a pure retro-bulbar neuritis, so that in speaking of a primary or secondary atrophy this exception should be borne in mind.

A third type of optic-nerve atrophy is that described by Leber as *retinal atrophy*. This results from any extensive disturbance with the nutrition of the retina, and depends generally upon retinitis pigmentosa or extensive retino-choroiditis. In this class of cases we find the most extreme changes in the blood-vessels. In advanced cases of retinitis pigmentosa the vessels are very small, and sometimes are so reduced as to be indiscernible with the ophthalmoscope. The disk has a dirty-bluish or yellowish-gray hue.

In the various forms of retino-choroiditis the changes in the vessels and the appearance of the disk are not apt to be so extreme; but where there is a large area of destruction, particularly at the macula, a corresponding sector of the nerve is generally atrophic.

The atrophy which follows embolus or thrombosis (*embolic atrophy*) of the central artery is also largely retinal in its origin—*i. e.* it depends not so much upon the interference with its own blood-supply (for this is in good part derived not from the central vessels, but from those of the sclero-choroidal ring) as upon a degeneration following the death of the nerve-elements in the retina. It gives the nerve a dense, opaque whiteness or a yellowish-white tint (Plate 6, Fig. IV.).

Subjective Symptoms.—Except in the cases following retro-bulbar neuritis of the macular bundle of fibers the *disturbance of vision* most commonly takes the form of a reduction of central acuity with contraction of the field at the periphery, but central and ring-shaped scotoma, sector-shaped defects, or spurious hemianopsia, all may occur (for visual fields see page 477). The *color-sense* is apt to suffer early in the course of the disease, the outer limits of the color-fields sometimes being irregular or contracted before the field for white shows any abnormality. A diminution of the *light-sense* is also common, the periphery of the field often showing a contraction, if it be tested with gray paper or by reduced light, when the ordinary test with a white object shows no abnormality (see page 168). On the other hand, some patients, especially in the atrophy accompanying retro-bulbar neuritis, see better in proportion by a moderately dim light. In the occasional cases where the functions are normal and the disk decidedly atrophic-looking, we have to assume either some congenital peculiarity or that the connective tissue

has been changed chiefly in appearance, without sufficient increase in volume to cause atrophy of the nerve-fibers.

Etiology.—It is evident that any of the causes which have been enumerated as producing optic neuritis may produce atrophy, and, as the signs of neuritis may have disappeared by the time the patient is first examined, the results of the cause may be set down as atrophy without any knowledge of the neuritis. Besides neuritis, any other cause that cuts off communication between the retina and the higher nerve-centers will produce atrophy.

Brain-tumors may cause atrophy, by the production of neuritis, by direct pressure on the nerve, chiasma, or tracts, by the pressure upon the chiasma and tracts of the accumulation of fluid in the ventricles which often accompanies them, or by raising up the chiasma and nerve, and thus causing them to be constricted by the arteries at the base of the brain.

Injuries to the nerve-trunk are followed by atrophy, both ascending and descending, while all the various processes which destroy the function of the retina, whether it be removal of the globe, the various conditions which produce phthisis bulbi, inflammations of the choroid or retina, detachment of the latter, or cutting off its blood-supply through thrombosis or embolism, and, finally, abnormal pressure both upon the retina and the disk, as in glaucoma, produce ascending atrophy of the nerve-trunk, chiasma, and the tracts leading to the higher cerebral centers.

The atrophy which sometimes follows *erysipelas* of the face is undoubtedly caused by the accompanying inflammation in the orbit, since any severe *orbital cellulitis* may cause atrophy, probably either by direct pressure on the nerve-trunk, by thrombosis of the retinal vein, as pointed out in particular by Knapp, or by producing a neuritis. Some authors doubt whether atrophy may result simply from *hemorrhage into the orbit*, but the writer has seen at least two cases in which this undoubtedly occurred: in one a hemorrhage followed an extirpation of the lachrymal gland and led to atrophy, with the typical picture of thrombosis of the retinal vein and paralysis of all the ocular muscles; this indicating that even if the vein had not become obstructed, atrophy might have resulted directly from the pressure.

In a number of cases optic-nerve atrophy follows *falls* or *blows upon the head*, without any signs of meningitis or optic neuritis. The first rational explanation of these cases was given by Hölder and Berlin, who found that in many cases, without any external signs of fracture, fissures of the walls of the orbit were produced which extended into the optic canal, the nerve in some cases apparently being injured immediately by pressure from fragments of the bone or by hemorrhages into the optic canal, or later by pressure from the development of callus. In the first two instances blindness develops at once; in the last it comes on gradually after several days or weeks. These cases are generally one-sided, and apparently may be produced through *contre-coup* by violence to distant parts of the body. Whether the cases described by Schweigger as *concussion of the optic nerve* were due to fractures of the bone is uncertain. In them violence to the head was followed by immediate and complete one-sided amaurosis. A certain amount of useful vision (in one case nearly approaching the normal, the nerve showing partial atrophy) returned after some days or weeks. It is possible, also, that some of the atrophies which follow *spinal injuries* are produced in this way: about the real significance of these cases there has been some dispute, some authors leaning to the view that they were the result of a trophic disturbance, while others assume that they result from an ascending meningitis; but since it has been shown that a fall upon the trochanter, for instance, can produce a frac-

ture through the optic canal by contre-coup, it seems probable that at least some of the cases have this origin.

The numerous cases of optic-nerve atrophy in various forms of *spinal disease* also led to the belief, at one time prevalent, of a trophic connection between the spinal column and the optic nerve; and because the disk in many of these cases (though by no means in all) was of a grayish hue, it was common to speak of *gray* or *spinal atrophy*. The spinal affection in which atrophy is most commonly observed is *tabes*. Out of 109 cases of *tabes* which Berger examined he found optic-nerve atrophy in 44, and amblyopia with normal disks in 7. It may be one of the earliest symptoms of the disease, occurring entirely independently of the spinal lesion, and beginning, apparently, near the peripheral end of the nerve. In the early stages the ophthalmoscope sometimes shows a decided congestion of the disk, though the ophthalmologist seldom sees the patient early enough to observe anything but atrophy, which may be either of the gray or white variety. The disturbance of vision generally takes the form of a peripheric contraction of the field with reduced central acuity, but central scotomata sometimes occur. The affection almost always ends in complete blindness if the patient live long enough.

In *disseminated sclerosis* the frequently occurring atrophy, which is often confined to the other half of the disk and produces a relative central scotoma oftener than a contraction of the field, is sometimes preceded by moderate papillitis, and is much less likely to lead to blindness than the atrophy of *tabes*. The disturbance of vision is more subject to variations, and is not infrequently accompanied by *nystagmus*, which becomes more marked or shows itself only on *voluntary* movements of the eye.

In *progressive paralysis*, also, optic atrophy is quite common, and that it may be a very early or perhaps an initial symptom is indicated by the fact that a large proportion of patients in whom apparently idiopathic optic atrophy occurs sooner or later become demented. Here, too, Allbutt has observed a stage of congestion preceding the atrophy.

According to Michel, the atrophy occurring in multiple foci of *cerebral softening* as a rule affects only the temporal side of the disk. Atrophy has also been observed in *chronic bulbar paralysis*, in *chorea*, in *epilepsy*, where it is probably only a coincidence, and in nearly all of the general affections which have been mentioned in connection with neuritis.

Atrophy is quite common in *diabetes mellitus*; it also has been noted with *diabetes insipidus*. One important cause of atrophy is *pressure upon the nerve or chiasma* at the base of the brain or within the optic canal by enlarged arteries. The enlargement may be aneurysmal, but commonly it is merely the result of arterial sclerosis, and the resulting pressure on the nerve may spread the latter out in the form of a semi-cylinder or even divide it into two bundles.

The atrophy which follows severe *hemorrhages* is sometimes preceded by neuritis. The blindness is often complete and generally double-sided. It comes on sometimes at once, but, as a rule, several days after the hemorrhage, and, according to Fries, out of 90 cases the highest degree of amaurosis attained in the course of the case underwent no improvement in 43; in 28 partial recovery took place, while full vision was restored in 19 cases. The sources of the hemorrhages are most frequently the alimentary canal (stomach and intestines), the uterus, veins (venesection), the nose, accidental wounds, the lungs, and the urethra, in the order named. Women are attacked with only slightly greater frequency than men. The immediate cause of blindness

is probably, in the cases occurring at once, ischemia of the nerve and retina; in the others hemorrhages into the nerves, nerve-centers, or intervaginal space from malnutrition of the vessel-walls. In one case a microscopic examination showed fatty degeneration of the nerve-fibers and retina.

Incurable atrophy has occurred in some cases of *lightning-stroke*, while in one reported case the pallor of the optic disks, the small retinal vessels, and the great reduction of sight improved to normal or nearly so on the use of nitro-glycerin.

The atrophy from *affections of the accessory sinuses* will be discussed later on.

Under the head of *congenital atrophy* are grouped a number of cases, probably of various origins, which have been observed in infants. Some of these are doubtless the result of neuritis or of hydrocephalus *in utero* or soon after birth; in others, judging from the entire absence of retinal vessels, there is a fault of development; while still others, which have been observed especially after *forceps delivery*, are probably the result of injury to the bones of the head.

Hydrocephalus internus, although, as has been mentioned, it sometimes produces neuritis, is generally found to have produced atrophy, probably by direct pressure upon the chiasma and tracts.

In quite a large proportion of cases—Leber estimates it as high as 50 per cent.—the most careful examination fails to reveal any cause for the atrophy. In these cases and in those occurring in the course of spinal diseases men far outnumber the women, and old persons the young. In all forms of atrophy, except where caused by affections of the orbit, globe, or accessory sinuses, double-sidedness is the rule.

Pathology.—In the atrophy following neuritis, largely as the result of pressure both from the edema and the new connective tissue, the nerve-fibers degenerate, their sheaths (in the medullated portions) being first transformed into fatty-looking globules and granules, leaving only the nerve-fibrils, which themselves become varicose, and then shrink into very fine homogeneous fibrillæ or disappear altogether. The new connective tissue may fill up the papilla entirely, and the larger vessels running through it generally have much thickened walls.

In the simple or gray atrophy ("gray atrophy," in a pathological sense, refers strictly to the macroscopic appearance of the cut surface of the nerve) a similar process of degeneration takes place without any ascertainable preceding inflammation. It may occur in isolated foci or may affect the greater part of the nerve at once. In old, extreme cases, either of simple, neuritic, or direct-pressure (from tumors, etc.) atrophy, all signs of nerve-substance may disappear entirely, and only a cord of connective tissue remain.

In a certain sense "normal" optic atrophy has been reported by Fuchs in the form of degeneration of a number of the most peripheric bundles of fibers in a large proportion of healthy adults. This observation is disputed by Michel.

Diagnosis.—The variations in the normal color of the disk are such that it is sometimes impossible to say whether an observed pallor is abnormal or not. Here the subjective tests are of great importance, the *examination of the field* for white and for colors being made with the utmost care both by full and by reduced light. To illustrate the importance of this a case may be mentioned in which, with decided atrophy of one-quarter of the disk of one eye, with an absence of one quadrant of the field for white and of the nasal half of the field for colors, no trouble was suspected with the other eye,

it being apparently normal both subjectively and objectively. But, while the vision was practically normal and its field showed no defect for white, an examination of the color-limits showed that in the nasal half of the field both quadrants had lost the perception of green, and one quadrant that of red, thus indicating with the greatest probability the implication of both nerves or of the chiasma.

In other cases, as mentioned above, an eye showing no defect in the field by good light will, when tested in a moderately dim light or by using a gray paper as a test object, show marked abnormalities. In many cases, where there is no question about the existence of atrophy, a careful consideration of the symptoms is of importance in the attempt to determine the location of the primary lesion or to decide on the nature of the general disease of which it is but one of the manifestations. Where the trouble is entirely one-sided the lesion must, in the great majority of cases, be peripheral to the chiasma, but not necessarily, for an intracranial lesion might affect one side of one optic tract so as to produce a one-sided disturbance of sight, either crossed or on the same side. In nearly all cases, however, any affection of the chiasma or tracts will produce a double-sided disturbance in the fields, generally more or less symmetrical, pressure on the chiasma in front or behind tending to produce defects in the temporal halves of the fields; while symmetrical defects in the nasal halves indicate pressure on or lesion of the outer side of the chiasma, tracts, or intracranial portions of the nerves (see pages 480 and 481).

An *enlargement of the blind spot* may indicate the existence of the so-called normal atrophy of Fuchs (granting that this actually occurs), or a mild peripheral perineuritis, or some other affection attacking only the fibers close to the periphery toward the distal extremity of the nerve. A *central scotoma*, either relative or absolute, indicates, of course, an affection of the papillo-macular bundle of fibers, but, unless there have been symptoms of congestion of the disk to indicate an implication of the distal extremity of the nerve, we have no way of judging whether the lesion is nearer the globe or the brain unless there occur with it an enlargement of the blind spot; in which case, as Berger has recently pointed out, we may with some certainty diagnose *distal perineuritis*, either present or past. In deciding between atrophy from tabes and from disseminate sclerosis it should be remembered that disorders of the pupil-reaction are much more common in tabes, while nystagmus of recent origin and paresis of other than ocular muscles strongly indicate disseminate sclerosis. The partial atrophy occurring in cerebral softening has already been referred to. In all cases of atrophy, as of neuritis, the importance of as thorough an examination as is practicable of the general system, reflexes, urine, etc. should not be forgotten.

Prognosis.—The prognosis of *post-neuritic atrophy* is, like that of the neuritis itself, relatively favorable, since the sight that is left after the neuritis has run its course is apt to be retained. In some cases normal vision is kept, but, as a rule, there is a reduction of central acuity with contraction of the field, except in cases in which the lesion has mainly affected the papillo-macular bundle, where a central scotoma with normal peripheric field-limits is the rule.

In the cases of *simple atrophy* the prognosis will depend upon the cause if this can be ascertained. In tabes it is almost unqualifiedly bad: once having set in, the loss of sight generally progresses until the patient is blind. In disseminate sclerosis blindness is rare, and in some cases the vision, after being much reduced, undergoes considerable improvement. In the other

cases of simple atrophy the prognosis must always be dubious if there is evidence of recent progress. The majority of them sooner or later, in spite of all treatment, end in blindness. Yet the surgeon must be careful not to be too positive in his expressions of pessimism, for every now and then one sees a patient apparently doomed to blindness, one eye being already practically blind, with marked symptoms of progressive atrophy in the other, where to his surprise the process stops and useful sight is retained for years.

In *toxic amblyopia*, the papilla occasionally presents the appearance of a general atrophy, and where this occurs, with some slight contraction of the field, with myotic pupils, and with peripheral paralysis due to alcoholic neuritis, the diagnosis of some grave incurable disease may be erroneously made in spite of the central scotoma, since such scotomata are not infrequent in some such diseases, and sometimes, though rarely, occur in tabes. On the other hand, a too favorable prognosis may easily be made with patients who have atrophy of the outer quadrant or half of the papilla, with a central scotoma, relative or absolute. In such a case, if the patient happen to use tobacco or alcohol freely, it would be natural to think of toxic amblyopia and give a relatively good prognosis, although the use of these stimulants may be a mere coincidence, and the trouble may continue to progress in spite of total abstinence, the atrophy being due to some entirely different cause. In two cases of this kind, which the writer has seen, the central scotoma was decidedly less marked, in proportion to the amount of atrophy and reduction of vision, than is usual in toxic amblyopia. The only safe plan, if there are no indications of disseminate sclerosis, cerebral softening, or other serious nervous disease, is to await the result of abstinence before making a diagnosis or prognosis.

In the rare cases of *spurious hemianopsia*, when, with *progressive atrophy*, the fields happen temporarily to closely resemble those in homonymous hemianopsia, the beginner might consider it to be a case of cortical hemianopsia and give much too good a prognosis as to the chance of progression. In such cases the history, the more pronounced atrophy of the disk, the undue reduction of the central vision, and the disturbance of the light- or color-sense in the remaining halves of the fields, will almost certainly allow the proper distinction to be made.

Where from the previous existence of a large physiological excavation, or from an unusually high normal intraocular pressure, or from the nature of the initial lesion, a case of simple atrophy exhibits a deep, sharp-bordered excavation, the problem of distinguishing it from *simple glaucoma* with no appreciable hardness of the globes may arise, and its solution may be very difficult or, in some cases, at first impossible. There are no points of difference upon which absolute reliance can be placed. The most valuable are the occurrence in glaucoma of an unusually good color-sense in proportion to the contraction of the field, and the ease with which pulsation of the retinal arteries may be produced by light pressure on the globe. All the conditions have to be carefully weighed in such a case, and occasionally no positive diagnosis can be made at once. If, after continued observation, the doubt should persist, it is better to use a myotic, or even to operate, than to allow the patient to go blind by default. (Compare with page 382.)

Treatment.—The results of the treatment of optic-nerve atrophy are extremely unsatisfactory. It is entirely probable that, except where it depends upon some still active inflammatory process, upon some toxemia, or upon some neoplasm which can be removed, no form of treatment has any influence upon it. This does not mean, however, that nothing should be

done for the patients. In the hope that there may still be some active process capable of being influenced, large doses of iodid of potassium may be tried, or mercury may be used if there is any suspicion of syphilis, though, as a nerve-poison, it should be used with great care if there is any spinal trouble. It is common to use strychnin in many of these cases, and it is probably well to try it in full doses (increasing from $\frac{1}{20}$ grain three times a day, if given by the mouth, to the limit of toleration, or injecting from $\frac{1}{40}$ to $\frac{1}{20}$ grain under the skin of the temple. It often causes a slight temporary improvement of central acuity or of the extent of the field, and a number of cases have been reported in which its effects have seemed almost miraculous. In conjunction with strychnin, nitroglycerin should be exhibited.

Electricity in the form of a mild constant current may be used for a few minutes every day or two, though little more can be said for it than that it gives the patient the benefit of the doubt. Nitrate of silver is another remedy in common use which is supposed by some observers to have a particular value in checking post-neuritic atrophy, and cyanid and arsenite of gold, phosphate of zinc, and numerous other remedies have received enthusiastic recommendations. Where there are evidences of active inflammation at the base of the brain a vigorous course of salicylate of sodium, iodid of potassium, inunctions of mercury, or some form of sweat-cure, or any two or three of these together, should never be omitted. The writer's plan is generally, as in the case of neuritis, to give the salicylate a trial of about a week (15 grains eight to twelve times a day in brandy); then, if no decided effect has been produced, to change to large doses of iodid in connection with the sweat-cure (pilocarpin $\frac{1}{5}$ to $\frac{1}{3}$ grain in a glassful of hot whiskey and water, with the addition of 15 grains of salicylate of sodium if the pilocarpin alone does not produce free diaphoresis).

It is in these cases of meningitic atrophy that Valude has recommended antipyrin.

Tumors of the Optic Nerve.—The *primary tumors* of the optic-nerve trunk are most frequently of the sarcomatous type, with a tendency to myxomatous degeneration. Sarcoma, myxo-sarcoma, myxoma, and myxo-fibroma are the commonest types, in the order named, though glioma, psammoma, endothelioma, and neuroma have also been described, the last named very rarely.

The point of departure seems to be the pial sheath and the septa of connective tissue running off from it into the interior of the nerve, the tumor sometimes developing uniformly throughout its diameter, but more frequently with a tendency at first to spread along the pial sheath in the form of a cylinder, through the center of which the more or less degenerated trunk of nerve-fibers runs, though at the oldest portions its identity is often entirely lost. These tumors are generally somewhat spindle-shaped, tapering at least at one end. They never invade the globe (unless a recent case of Risley is an exception), and when they grow forward close to it a sharp constriction separates them from it; when the tumor is continued into the cranial cavity there is a narrowing corresponding to the optic canal.

From a pathological standpoint, though not necessarily differing in the symptoms which they produce, are to be distinguished the growths which take their origin in the dural sheath. They are apt to be fibromata, endotheliomata, or sarcomata; they generally affect the nerve-trunk only by direct pressure or by interfering with its blood-supply.

As *secondary tumors* glioma and melanomatous sarcoma, spreading from the interior of the globe, are most common. Carcinoma has also been

observed, in one case as metastasis from the kidney; in another, that of Krohn, already referred to as unique, a metastasis from a carcinomatous ovary occurred in each optic nerve immediately behind the globe. Gummata and sometimes very extensive tuberculosis of the optic nerve have also been reported. In the case of Sattler the tuberculosis of the nerve and its sheaths produced a tumor 18 mm. in diameter by 25 mm. in length. Michel has reported an unique case in which a patient, suffering from elephantiasis of the leg, but with good sight, was found after death to have the chiasma and the intracranial portion of one nerve very much thickened by the uniform distribution, between the bundles of fibers, of numerous fibrils similar to those of elastic tissue.

Symptoms.—Tumors of the nerve are apt to occur in children, and there is a certain amount of evidence to indicate that contusions of the eye and its vicinity play a part in their etiology, though sometimes their beginnings are probably congenital: Their growth is slow, and pain occurs, if at all, only after they have attained considerable size. If the patient is a child, usually the first symptom to attract attention is protrusion of the globe. This is at first, and sometimes throughout, straight forward, but as the tumor gets larger its impingement upon the upper and inner walls of the orbit sometimes forces the eye slightly down and out. In this stage the general motility of the globe is sometimes impaired, while in the early stages it is remarkably well preserved.

If examined early, the eye may show signs, sometimes very pronounced, of optic neuritis; later on, of atrophy. The pupil may be wide through pressure-paralysis of the oculo-motor or from the loss of sight. In older patients the existence of the tumor is frequently first suspected from the loss of sight, which generally progresses rapidly, though to this there are occasional marked exceptions, as in the case of v. Graefe, where the chiasma and adjoining portions of the optic nerve were found converted into a gliomatous tumor in which it was difficult to make out any of the scattered nerve-fibers, although up to a short time before death the sight had been more than normal. In a more recent case of Wiegman, a well-developed tumor of the trunk of the nerve, spreading the bundles of fibers widely apart, existed with a vision of $\frac{20}{20}$ (in the other eye $\frac{20}{30}$) and a normal field. In such cases the development must have taken place very gradually, so as to allow the nerve-fibers to accustom themselves to the pressure and change of position.

Diagnosis.—The main points in the diagnosis between these and other tumors of the orbit are the slow and relatively painless progress (though this may apparently be hastened by an injury), the propulsion straight forward or nearly so, the long-retained motility of the eyeball, and, with the exceptions noted above, the early loss of sight.

Prognosis.—Prognosis as to sight is of course unqualifiedly bad, that as to the chance of retaining the globe fair, while as to the prevention of recurrence after removal it is decidedly good unless there be involvement of the extra-orbital part of the nerve. To help decide this point, an examination of the field of the other eye is very important, for if it show a well-marked defect, without other cause, an implication of the chiasma is probable; and, while this should not necessarily contraindicate an operation, the prognosis should be very carefully guarded.

Treatment.—Removal is the only treatment allowable, and it is probable that this can, in the majority of cases, be done with retention of the eyeball, although hitherto the globe has in most cases been sacrificed also. In 8 cases, beginning with one of Knapp's, the nerve has been cut close to the eyeball and

at the extreme apex of the orbit, and the intervening portion of the nerve with the tumor removed, the eye being left in place. In most cases, the internal or external rectus muscle was cut to aid in exposing the tumor, but in one case (Knapp's second one) the tumor could be brought into view through an incision between the internal and inferior rectus and removed without cutting any muscle. In 4 of these cases the eye retained its normal appearance, in 3 it became more or less phthisical, and in 1 there was sloughing of the cornea through exposure from extreme protrusion. The method to be recommended is that of Lagrange,¹ who enlarges the external commissure, cuts the external rectus, leaving attached to it a long thread, puts a thread through the tumor by which it is drawn forward as far as possible while the nerve is being cut at the external optic foramen. The nerve is then cut close to the globe, the tumor removed, and the external rectus and conjunctiva reunited. Since one of the subsequent dangers is sloughing of the cornea from exposure (in Knapp's case this occurred in spite of repeated suturing of the lids), it is well to check the bleeding as quickly as possible by pressing back the ball firmly before stopping to suture the muscle; this is to be followed by a pressure bandage and prophylactic lid sutures.

Hyaline Bodies in the Optic Disk.—These bodies (known also as *colloid bodies*, *verrucosities*, or "*Drusen*") were first discovered in microscopical specimens examined by Müller and by Iwanoff, and for years little was known of the ophthalmoscopic picture which they presented.

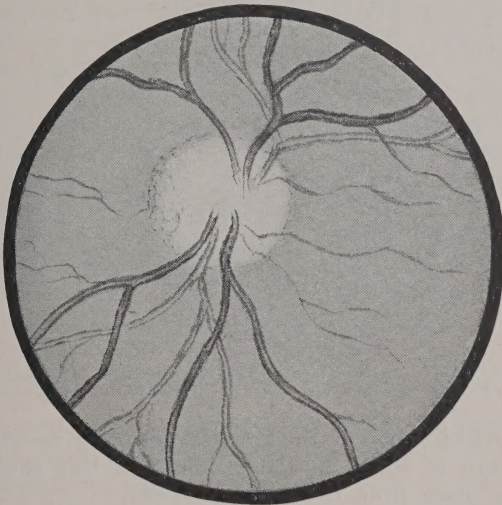


FIG. 264.—Moderate development of hyaline bodies at border of optic disk.

Symptoms.—When seen during life, if there are but few of them and they are rather deep-seated, they can be barely distinguished as somewhat spherical bodies of a lighter hue than the rest of the disk. In this case they are best seen, as Liebreich suggested, by throwing the brightest part of the light a little to one side of them. When nearer the surface they may be scattered through the disk or occur more commonly in groups at its periphery (Fig. 264). They are somewhat translucent, and in some cases give back quite a brilliant reflection. When they project well above the surface of

¹ Krönlein's plan of temporarily resecting the outer bony margin of the orbit may be employed, but it probably is very seldom necessary in optic-nerve tumors.

the disk they often remind one of half-soaked grains of tapioca. In other cases they are of a denser or slightly yellowish white. In the direct image, they appear to be about 2-3 mm. in diameter, but occasionally bodies two to three times as large are seen. The entire border of the nerve is occasionally obliterated by them, and sometimes they encroach upon the disk so as to entirely conceal its normal tissue, in its place appearing a mulberry-like mass, from the center or sides of which the blood-vessels appear. A slight encroachment upon the retina is common, and occasionally isolated granules are seen well out from the main body. More rarely large masses of them develop out from the edges of the disk into the retina. Fig. 265 represents such an

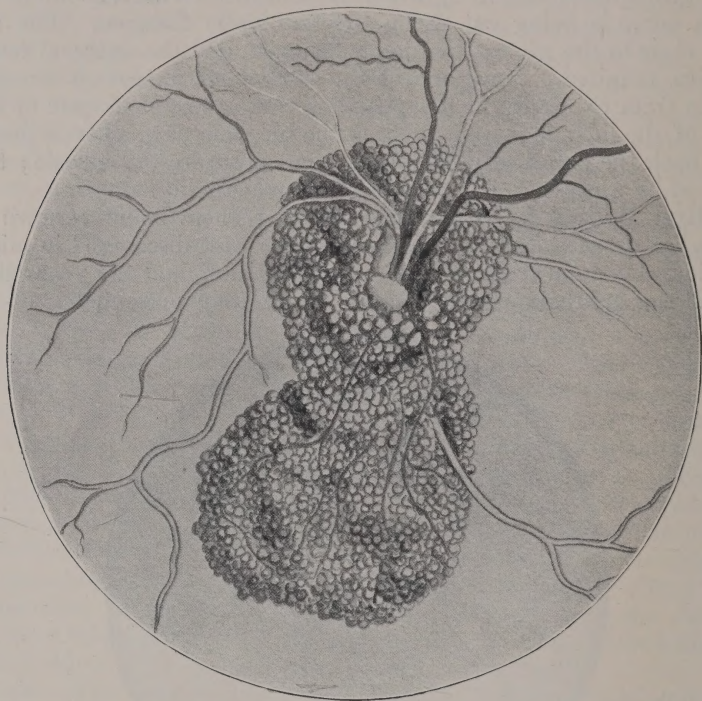


FIG. 265.—Extreme development of hyaline bodies in optic disk and retina.

extreme case, in which some of the arteries appeared as white cords with a very minute column of blood in the center. In this case, repeated small hemorrhages took place from the retinal vessels.

The affection is a rare one, occurring in the writer's experience in 1 out of about 2000 cases. It is met most frequently in cases of retinitis pigmentosa, but, aside from this, the eyes in which it is seen with the ophthalmoscope are, in other respects, often entirely normal, though there is some rather unsatisfactory evidence tending to connect its origin with injuries to the eye, with neuro-retinitis, and with Bright's disease.

Few cases have been observed long enough to note any change in the ophthalmoscopic appearance, but where this has been done a gradual increase in the number of the bodies has sometimes been noticed. It is generally stated to be a double-sided affection of advanced life, but the writer has seen it quite as often in young adults as in older patients (in one case at nine years), and in one disk alone as often as in both disks.

Pathology.—Our knowledge of the more intimate character of these bodies we owe chiefly to Hirschberg and Cirincione, Gurwitsch, de Schweinitz, and Sachsaler. They are found to be made up of a rather hard hyaline substance, the smaller bodies, on cross-section, showing well-marked concentric lines, the larger bodies being made up of a number of the smaller ones more or less blended together. At points they show a tendency to calcareous degeneration. Tincture of iodine gives the substance a yellowish color, and no amyloid reactions are obtained with saffranin and methyl-violet. The earlier view was that these bodies had the same origin as the colloid excrescences of the *lamina vitrea* of the choroid, while the tendency at present is to regard them as something entirely different. It is certain that they have no necessary connection with the *lamina vitrea*, for, while a favorite place for the development of the largest masses is just between the termination of this membrane and the central vessels of the nerve, they may also occur well out in the retina and in the nerve, posterior to the *lamina cribrosa*. Granting this, it has not been shown that their composition differs essentially from that of the "Drusen" of the choroid (consult Fig. 318, page 496).

Diagnosis.—In the less pronounced cases, the affection is easily overlooked, for it is only by careful examination by the direct method that the rounded outlines of the bodies can be made out. In a more pronounced form, especially where they are grouped around the periphery of the disk, they may be and have been mistaken for optic neuritis, from which, however, a careful direct examination will always enable them to be distinguished. The most pronounced cases look like nothing else to be seen at the disk, but they might easily puzzle the beginner, especially since, in many text-books, they are not mentioned.

Prognosis.—In the cases observed during life, the vision has usually been found to be normal (except in the cases accompanying retinitis pigmentosa), in some, even where they were so abundant as to nearly conceal the disk; and where moderate development of them is discovered by accident, as is generally the case, they need cause no alarm, but it remains to be seen whether in extreme and progressive cases they may not cause serious trouble. The case represented in Fig. 265 was one-sided, and the eye was entirely blind, but it is not certain that the blindness may not have been due to some other cause.

Treatment.—Treatment is not necessary in the great majority of cases, and it is not easy to understand how anything could be used that would affect them.

Hemorrhages in the Optic Nerve or in the Intervaginal Space.

—After a hemorrhage at the base of the brain or in the optic canal, or even from a more peripheral source (after a contusion of the eye), the blood may flow into the intervaginal space and distend it widely at its distal extremity.

In such cases the sight may be suddenly lost, the ophthalmoscope showing a somewhat blurred disk, with the central vessels reduced in size, sometimes with a red spot at the macula surrounded by a grayish area, as in embolus of the central artery, and, later on, the dissolved hemoglobin may find its way into the disk, so as to be seen with the ophthalmoscope, leaving deposits of pigment there by which the nature of the original process may be recognized after months or years. The nerve atrophies, and the vision does not return at all, or does so but imperfectly. Where there is no history of violence the affection might be mistaken for a rapidly developing neuritis or for embolus or thrombosis of the central artery, which latter may indeed possibly be produced by it.

Much more rarely a hemorrhage occurs within the pial sheath, and may find its way along the septa of the nerve-trunk. This has been observed in connection with Bright's disease.

Optic-nerve Lesions from Affections of the Accessory Sinuses.

—Inflammation of any of the sinuses or of the ethmoid cells may cause optic neuritis and atrophy, by spreading to the orbital tissue or to the cranial cavity; or by the direct pressure of their distended walls upon the orbital tissue, in the case of the ethmoid cells, and possibly of the maxillary and frontal sinuses.

Affections of the sphenoidal sinus have an especial significance for the ophthalmologist on account of the intimate relation between the walls of this cavity and the optic nerve. Fig. 266 shows part of a coronal section

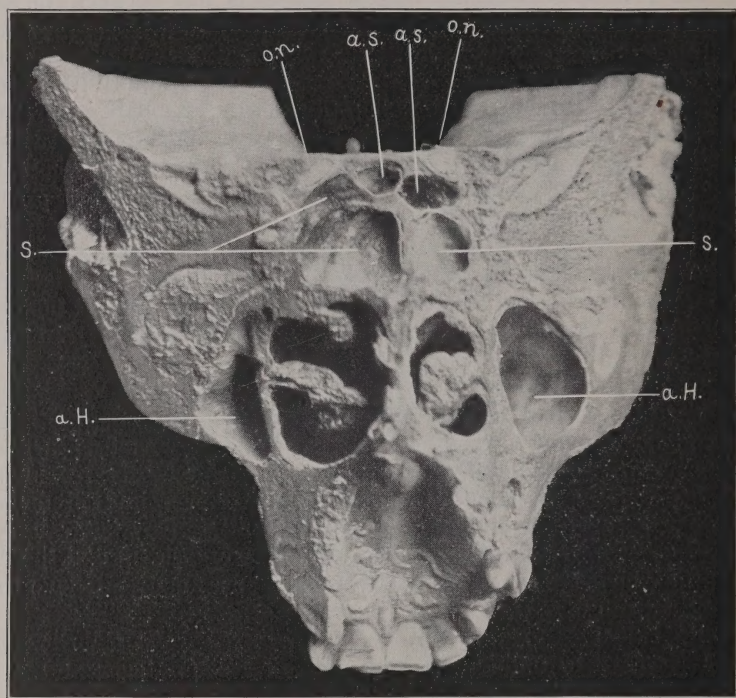


FIG. 266.—Coronal section through posterior part of optic canal: *o.n.*, optic nerve; *s.*, sphenoidal sinus; *a.s.*, anterior sphenoidal or posterior ethmoid cell; *a.H.*, antrum of Highmore.

through the skull passing through the optic canals. A glance at the left side of it, with a realization of the fact that the thin bony partition separating the optic canal from the sinus is sometimes imperfectly developed, will show how easily an inflammation of the sinus might cause localized neuritis, with subsequent descending atrophy, through the diffusion of ptomaines into the nerve, or an actual infection of the intervaginal space, leading to perineuritis and choked disk; or an atrophy through direct pressure, if the walls of the sinus were distended by fluid or by a tumor. These considerations should lead one to take the sphenoidal sinus into account in all cases of obscure optic-nerve trouble, especially since at least one case has been reported (Holmes) in which a puncture of the anterior wall of the sinus drew off a collection of pus and cured an optic neuritis.

The right side of the section represented in Fig. 266 illustrates a point

which seems to have attracted very little attention—namely, that in some heads, on at least one side, the cavity in closest proximity to the optic canal is not the main sphenoidal sinus, but an entirely separate cell, opening into the nose by an independent foramen which is sometimes so large that the cell could, with propriety, be described as the upper extremity of the nasal cavity. A collection of pus in this space might cause a disturbance of sight, with symptoms of suppuration of the sphenoidal sinus, although an operation on the latter would give no relief. To operate on this anterior sphenoidal cell or prolongation of the nasal cavity would be more difficult and dangerous than to puncture the main sphenoidal sinus, but a knowledge of its occasional relation to the optic canal may serve to explain some cases of optic-nerve trouble in which an ordinary sphenoidal operation gives negative results.

Congenital Anomalies of the Optic Nerve.—Aside from *congenital atrophy* of the optic nerve due to intra-uterine neuritis, hydrocephalus, and other causes, the nerve in the various degrees of *microphthalmos* and *anophthalmos* shows more or less marked signs of imperfect development. It may be entirely absent, or represented only by a cord of connective tissue, or it may simply have an abnormally small proportion of nerve-fibers. Even more interesting is the case cited by Manz, which, though old, is apparently quite authentic, of entire absence of any decussation of the optic nerves, the latter running direct to the respective sides of the brain, without any sign of a chiasm.

Some of the anomalies of the nerve which have been discovered with the ophthalmoscope are discussed in the section on the Ophthalmoscopic Examination of the Fundus (pages 191–195). Of these, the condition known as *coloboma of the optic nerve* or *coloboma of the optic-nerve sheath* is the most important. In the most common type, one sees in place of the disk an excavation several times as large as the ordinary papilla, generally much deeper and with a sharply-excavated border below, while, above, its floor comes gradually up to the level of the surrounding retina; the main vessels curve abruptly over the lower edge, while the bottom of the excavation may be entirely free from them or may have some running across it to the upper part of the retina, crossing the upper border without any break in their continuity at that point. The excavation is surrounded by a generally complete pigment ring, outside of which there is often a narrow white zone or crescent. If there is any sign of normal disk-tissue, it is apt to be above. More rarely, the entire floor of the excavation is deep below the retina, with vessels curving sharply around its border at various points, though chiefly below and above (consult Fig. 141).

The few microscopical examinations which have been made of the common form of this anomaly show that it depends upon the non-closure of the fetal optic-nerve fissure; the central vessels enter the nerve proper only in part, or more commonly not at all, but enter the eye through the mass of connective tissue which takes the place of the dural sheath below. In one case (Magnus) the fissure seems to have been at the nasal side instead of below the nerve. The deep atypical excavations which are sometimes seen within the borders of otherwise normal papillæ are probably due to a less-marked failure of development of the same nature.

Another type of anomaly, which has also been described as *coloboma of the nerve*, consists in the absence of a zone of choroid (often wider below) around the otherwise moderately normal papilla, the blood-vessels appearing near the center of the latter and passing across the borders of the zone without any displacement or other sign to indicate any considerable excavation. These cases, in the opinion of the writer, would be more accurately designated

circumpapillary coloboma of the choroid, and to this class the cases exhibiting mere crescents of choroidal absence below the papilla are most probably allied.

Coloboma of the nerve is generally associated with imperfect sight and often with nystagmus or microphthalmos. It may affect one or both eyes, and its etiological relationship to coloboma of the choroid is shown by its

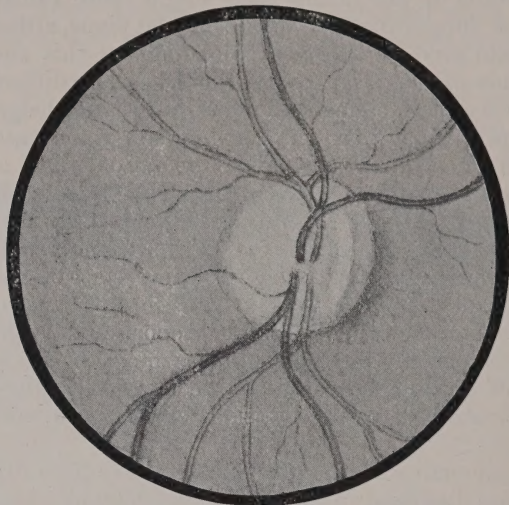


FIG. 267.—Band of connective tissue in optic disk.

occurring sometimes in the same eye with the latter, or in one eye of an individual having coloboma of the choroid and iris in the other eye.

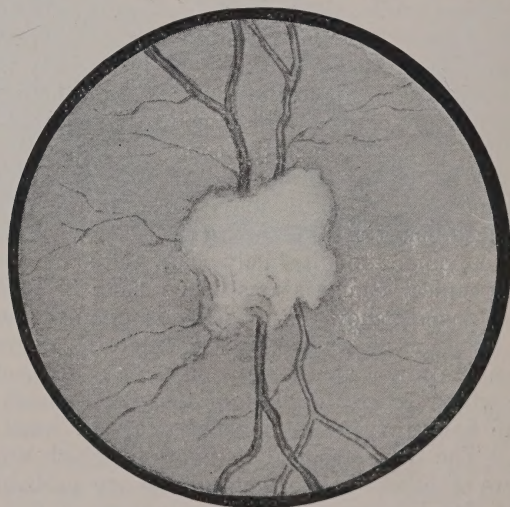


FIG. 268.—Extreme development of connective tissue in optic disk.

The *bands of connective tissue* not infrequently seen upon the disk may be, as Masselon suggests, prolongations of the lamina cribrosa, though they sometimes, as in Fig. 267, appear to have no connection with it. In extreme cases, as shown approximately in Fig. 268, the entire disk may be concealed by a pearly, bluish-white mass of connective tissue.

AMBLYOPIA, AMAUROSIS, AND DISTURBANCES OF VISION WITHOUT OPHTHALMOSCOPIC CHANGE.

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THE terms *amblyopia* (ἀμβλύς, dull, and ὤψ, the eye—i. e. obscurity of vision) and *amaurosis* (ἀμαυρος, dark, a marked blindness) have, since the days of Hippocrates, been applied to different degrees of loss of sight without sensible change in the ocular structures. The invention of the ophthalmoscope and the use of the microscope have greatly diminished the number of these affections, but there still remain "functional" diseases of the eye designated either by the dimness of vision (*amblyopia*) or decided loss of sight (*amaurosis*) that forms the most prominent symptom. Eyes blind from inflammatory diseases, as well as from certain congenital changes in the fundi, may also be described as *amaurotic*.

Congenital Amblyopia.—When an eye has never taken part in the visual act, as in cases of early squint, congenital cataract, corneal scars, or other obstruction to the light-rays, the accompanying dim vision may be altogether or partly the result of simple non-use; hence the terms *amblyopia*, *exanopsia*, and *argamblyopia* (Gould). In such cases, especially in squint, where the defective sight is largely due to the presence of high degrees of hyperopia or astigmatism, or both, correction of this ametropia, with exercise of the eye, may result in much improvement of sight or even in a return to normal vision. In other instances, however, correcting lenses do not help, and we may then conclude, even in the absence of positive signs, that structural changes or defects exist, probably in some portion of the extra-bulbar nervous apparatus.

In still another class of cases careful examinations with the mirror show in the nerve-head, retina, or choroid slight departures from the normal appearances. The papilla especially may be irregularly shaped or dimmed in outline, while the perimeter reveals *scotomata* and peripheral contractions of the field. Such anomalies as colobomata of the opticus, choroid, retina, and iris, as well as non-development of the whole eyeball (*microphthalmos*), are usually associated with, and are described as, examples of congenital amblyopia. Many of the ocular diseases of extra-uterine life also affect the fetal eye. Among these are glaucoma, iritis, chorio-retinitis, and diseases of the optic nerve, all of which have been classed with the congenital amblyopias.

Congenital Amblyopia for Colors (*Subnormal Color-sense; Color-blindness*).—Total absence of the color-sense (*achromatopsia*) is rare as a congenital condition and apart from disease, but it occurs to some extent and for some colors in about 3 per cent. of the whole population. It is quite rare (0.20 per cent.) in women, is sometimes hereditary, and is almost always bilateral.

By far the commonest form of color-blindness is exhibited when the

individual fails to detect the red and green in mixtures containing these colors. As a result of this defective color-sense, or *dyschromatopsia*, the pure greens are readily mistaken for grays and shades of red, and *vice versa*.

A less numerous class name correctly most of the saturated primary colors, but are very liable to miscall all or most of the color mixtures. They see little or no difference between orange and red, blue and purple, or violet and blue. In other words, they perceive in a compound only the predominating color. Artificial light generally adds to the difficulty which these persons experience in selecting colors.

The nomenclature of color-blindness is built upon various theories of color-perception; thus, the two forms of *dyschromatopsia* just described may be designated "red-green" and "blue-yellow" blindness, or we may, with propriety, speak of red, green, and violet *dyschromatopsia* (see also pages 98-100).

Whether the structural defects that give rise to the various forms of subnormal color-perception exist at the periphery or in the central portions of the optic tract, they are equally incurable (see also Appendix, page 603).

Reflex Amblyopia.—Both amblyopia and amaurosis have resulted from "reflex irritations" conveyed from remote organs, but such cases are rare. Loss of sight has been attributed to diseases of the reproductive organs, spinal cord, and digestive apparatus. Well-authenticated examples of amblyopia from intestinal worms, decayed teeth, diseases of the nasopharynx and its neighboring cavities (especially neoplasms and muco-purulent collections) have also been recorded. In most of these cases there were no fundus changes, and improvement or cure followed successful treatment of the distant lesion.

The etiology of reflex amblyopia is very obscure, and we must, for the present, continue to hold to the vague hypothesis of vaso-motor disturbances, affecting the nutrition of the retina in some instances and of the central ganglia in others, until similar mysteries of "functional disorders" elsewhere are cleared up. Probably some of these alleged reflex manifestations are really unrecognized cases of hysterical amblyopia.

Uremic Amblyopia, or Amaurosis.—This loss of vision occurs occasionally in the toxemia of Bright's disease, but is most frequently noted in those states of the system where albuminuria is found as a transient condition—viz. in pregnancy and the late stage of scarlatina. It affects both eyes, comes on suddenly, often lasts but a short time, and disappears as quickly as it came. It is almost always associated with other uremic symptoms, especially with convulsions, headache, vomiting, and coma. The blindness, which may be complete, is probably due to a temporary affection of the visual centers produced by the uremia.

The *prognosis* is uniformly favorable. Permanent blindness results only when organic lesions of the nerve and retina (albuminuric retinitis and optic neuritis) are present.

Ophthalmoscopically, nothing is to be seen in the retina, although several writers describe fulness of the vessels and a swollen appearance of the papilla.

The *treatment* is that of uremia.

Glycosuric Amblyopia.—Apart from the cataract of diabetic patients and those retinal and optic-nerve lesions that so closely resemble the fundus changes found in Bright's disease, there is sometimes observed a dimness of vision that simulates the amblyopia from tobacco and alcohol. There are, in these cases, no alterations visible with the mirror, but central scotomata for red and green can always be mapped out.

As the writer has elsewhere¹ pointed out, the *diagnosis* is somewhat difficult when the diabetic patient is a smoker, but in such instances the color-defect often extends to blue and white. In time white becomes involved at the periphery of the field also—a condition of things never found in pure tobacco or alcohol amblyopia.

The *pathology* is obscure, but Horner's views of the causation of alcohol-tobacco blindness may find acceptance in the case of glycosuric amblyopia—viz. that it is due to malnutrition of the macular fibers, in this instance brought about by glucose in the blood.

The *prognosis*, unlike that of tobacco amblyopia, which it resembles, is grave; in spite of treatment (of the diabetes) the case usually goes on to simple optic-nerve atrophy and terminates in total loss of sight.

Malarial Amblyopia.—It has been observed that during the course of intermittent fever and other diseases of malarial origin an amblyopia accompanied by fundus changes, and usually affecting one eye, may set in. The attacks are generally of short duration, but in some instances persist for weeks. The dim vision is commonly attributed to the action of the malarial poison upon the optic nerve and retina. It must not be forgotten, in this connection, that quinin, so universally administered in malarial diseases, is known to produce a temporary amblyopia quite apart from the well-known, serious fundus lesions of quinin-amaurosis, and the writer is convinced that some of the reported cases of malarial amblyopia are merely examples of the ocular symptoms of a mild quinin-intoxication.

True malarial amblyopia improves under quinin and other antiperiodics, and complete recovery is the rule.

Amblyopia from Loss of Blood.—The optic nerve bears even a temporary anemia very badly, and many secondary alterations in its tissues may be directly traced to malnutrition of a kind that would be successfully resisted by other nerves of special sense. Instances of a temporary loss of vision following excessive hemorrhage are quite common, especially from ulcer of the stomach or intestines. *Post-partum* floodings may also produce this form of amblyopia. An attack of dim vision may be the forerunner of *optic atrophy* (usually preceded by *optic neuritis*) setting in a week or ten days after the loss of blood. The papilla, at the time of the bleeding, is quite pale and the arteries are small.

Treatment.—The treatment of the primary amblyopia is the transfusion of blood or the intravenous injection of physiological salt solution. Diffusible stimulants and rest in bed, with small and repeated quantities of easily assimilated food, should be prescribed. These should be followed by tonic mixtures of iron and strychnin. The remedies employed for the relief of the later eye-troubles following profuse hemorrhage must be regulated by the form the fundus lesions assume.

Amblyopia from the Abuse of Drugs.—The poisonous agents that produce ocular symptoms are so numerous that anything like a complete account of all of them would be inappropriate here. In the following list the most important ones are italicized: *tobacco*, *alcohol*, *carbon disulphid*, *iodoform*, *lead-salts*, *quinin*, salicylic acid and other salicylates, cocaine, snake-venom, *mydriatic alkaloids*, *ptomaines*, carbolic acid, *male-fern*, aconite, chloral, *santonin*, picric acid, digitalis, tea, coffee, chocolate, gelsemium, ergot, coal-

¹ *The Toxic Amblyopias*, v. p. 14. For a full account of this matter see Dr. W. O. Moore's paper on "Diabetic Affections of the Eye," *N. Y. Medical Journal*, Mar. 31, 1888; Dodd: *Archives of Ophthalmology*, vol. xxiv. No. 2; Hirschberg: *Deutsch. med. Wochenschr.*, Mar. 26, 1891.

tar products, arsenic, naphthalin, potassium bromid, ergot, amyl nitrite, nitrobenzol, mercurial compounds, silver nitrate, antipyrin, curare, and a large number of other drugs.

Etiology and Pathology.—*Tobacco-, alcohol-, and tobacco-alcohol* intoxications present by far the commonest examples of toxic amblyopia. It is now admitted that alcohol or tobacco alone may produce partial loss of vision, but inasmuch as the smoker is usually a drinker and as the alcoholic commonly smokes, we almost always have to deal with mixed examples of intoxication.

Sachs (with the English school) believes that alcohol predisposes to tobacco-poisoning by producing dyspepsia. Horner is convinced that neither alcohol nor tobacco, as such, produces the pathological changes found in the opticus. Together these drugs produce a chronic gastric catarrh, which, in its turn, brings on a chronic anemia of the optic nerve, terminating in the retro-bulbar neuritis characteristic of alcohol and tobacco amblyopia.¹

Samelsohn, Uhthoff, and others have demonstrated by autopsies that the essential lesion in this disease is an axial, interstitial neuritis, beginning somewhere between the papilla and brain, and probably extending thence both toward the center and the periphery (see Plate 7). The fibers affected are those that supply the macular region—one-fourth or one-third of the whole number. The axis-cylinder and the true nervous elements mostly escape. The trabecular tissues enclosing these increase both as to number and size and press upon the nerve-fibers, bringing about their partial atrophy, just as the connective elements in cirrhotic liver and fibroid phthisis encroach upon the more highly organized tissues of the liver and lungs.

Recently, Nuel has revived the theory that central toxic scotoma is not primarily a neuritis of the macular bundle, but a disease of the macula lutea, causing degeneration of its cells, and that the optic-nerve changes are secondary to the destruction of the nerve-cells of the macula. Usher and Dean have observed macular-fiber degeneration follow experimentally-produced retinal lesions.

The majority of these cases occur in persons over forty years of age; examples of the disease in the female sex are uncommon, and we must remember that this form of toxic amblyopia occurs only in those who have an idiosyncrasy toward tobacco or alcohol.

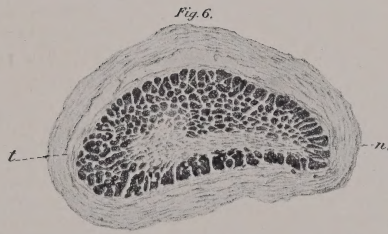
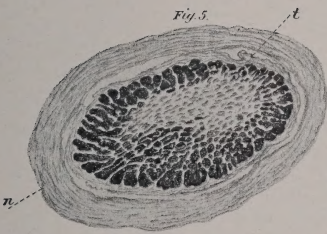
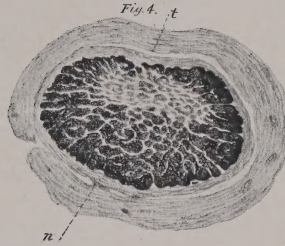
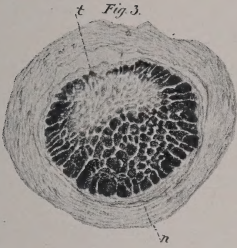
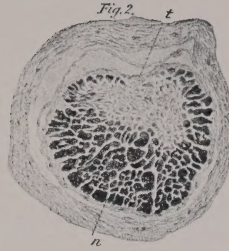
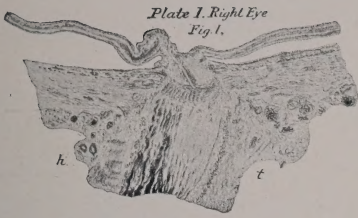
Symptoms.—The symptom most complained of is "misty" vision; the patient speaks of "seeing through a fog" or "through smoke." Even earlier than this he finds difficulty in reading or doing any other form of near work, for which he usually seeks glasses or requests to have his reading lenses changed. His visual acuity for both distance and near may fall as low as $\frac{6}{200}$ and J., 14. He now fails to distinguish red and green objects, and on examination with the perimeter negative central scotomata, in the form of horizontal ovals extending from the blind spots and including the fixation-points, can be mapped out (Figs. 269 and 270). Blue and white are rarely affected in pure cases of tobacco amblyopia.

Owing to the situation of the scotomata, most patients are *day-blind* and see best with a dilated pupil—*i. e.* toward evening or in a dimly-lighted room.

The mirror sometimes reveals alterations in the disk. When these are absent it may be assumed that the atrophic changes have not yet reached the

¹ The reader is referred, for a full description of all that is known of the toxic amblyopias, to Dr. Geo. E. de Schweinitz's work on that subject. A smaller and less complete monograph by the writer of this article, bearing the same title, appeared two years earlier.

PLATE 7.



Sections of the right optic nerve in a case of toxic amblyopia, showing degeneration of the papillomacular bundle; Weigert's stain (de Schweinitz).

FIG. I.—Longitudinal section of the posterior half of the right bulb and five millimeters of the optic nerve.

FIGS. II. and III.—Transverse sections of the optic nerve, eight and thirteen millimeters, respectively, behind the globe.

FIGS. IV. and V.—Transverse sections of the optic nerve in the region of the optic foramen.

FIG. VI.—Transverse section of the nerve in the intracranial region.

nerve-head. The most constant signs are hyperemia of the papilla in the early stages of the disease, and later a *triangular atrophic area*, occupying the temporal third of the nerve-head and corresponding to the macular bundle of fibers.

Diagnosis.—The diagnosis of the retro-bulbar neuritis produced by tobacco and alcohol rests upon the account just given.¹ The disease may

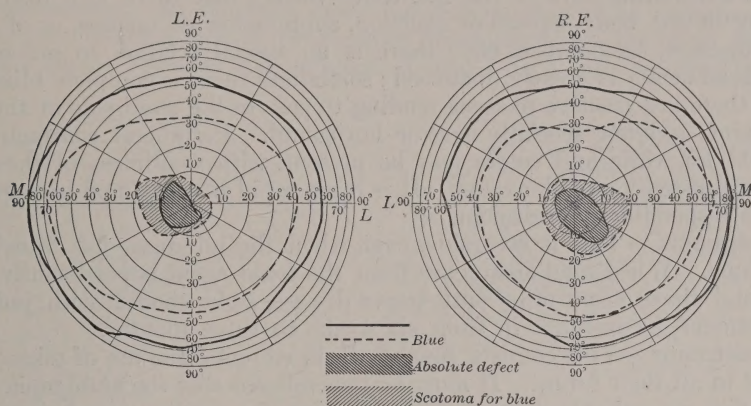


FIG. 269.—Alcohol amblyopia. Small absolute central defect, surrounded by a scotoma for blue (Uthoff).

be mistaken for non-toxic orbital axial neuritis, disseminated sclerosis, locomotor ataxia, and scotomatous atrophy of the optic disk. Everything considered, it is not difficult to differentiate these forms of ocular disease (see also page 447).

Uthoff thus summarizes the points of diagnosis between the retro-bulbar neuritis of tobacco and alcohol and that due to other causes, such as syphilis,

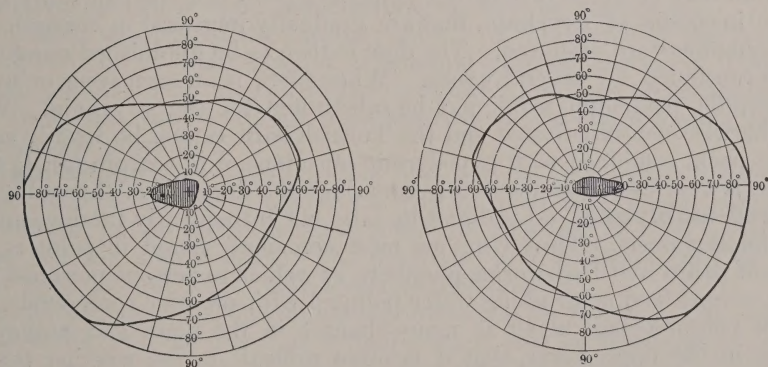


FIG. 270.—Typical oval scotomata from a case of tobacco-amblyopia. The patient, aged sixty, had smoked four pipes of tobacco daily, and an occasional cigar, since he was nineteen; a moderate beer-drinker (de Schweinitz).

rheumatism, disorders of menstruation, cold, diabetes, etc., as follows: 1. In true toxic amblyopia the central scotomata are almost invariably confined to red and green. 2. The scotomata and visual disturbances are bilateral, and the former are confined to the center of the field. 3. Vision does not fall

¹ For the differential diagnosis between the various forms of central amblyopia, see de Schweinitz, *loc. cit.*, pp. 85, 86.

below $\frac{6}{200}$. 4. The form of the scotoma is that of an oval, including both blind spot and fixation-point, with its long axis lying above the horizontal meridian. 5. The vision becomes *gradually* less. 6. The disease affects men above forty years of age. 7. *Pain is noticed on extreme ocular movements in essential retro-bulbar neuritis*, but is invariably absent in the toxic form.

De Schweinitz says of the non-toxic variety that there is a history of chilling of the body, excessive exertion, suppression of menses, or of infectious diseases, rheumatism, etc.; there is no special relation to sex or age. The visual acuity is greatly disturbed; sometimes there is complete blindness. Often there is a positive scotoma tending to pass to the nasal side of the fixation-point, and not specially oval or horizontal. Peripheral contraction of the field for white and colors may be present, with woolliness of the whole disk and distention of the veins. It is often rapid in onset, and is frequently slow in responding to treatment.

Prognosis.—This is favorable, even when the blindness has lasted for a long time. When total abstinence from the toxic agent is persistently practised and there is no other optic-nerve disease, sight should, with judicious management, be restored in from six weeks to three months.

Treatment.—This consists, first of all, in stopping the use of tobacco and alcohol in all their forms. It must be remembered that the amblyopia is but part of a general intoxication, and that chronic gastric catarrh is usually present. The digestive power is consequently often weak, and it should be fortified by appropriate means. Proper food, exercise, bathing, and regulation of the bowels are valuable adjuncts to tonic remedies. The Turkish bath has a decided value, especially in alcoholic cases. The chief aim should be to furnish a supply of good blood to the badly-nourished optic nerve. Most of the so-called specifics, nux vomica and strychnin particularly, are very useful, especially with pallor of the disk and when general toxic symptoms are present. Usually full doses of the elixir of pepsin, bismuth, and strychnin may be given internally. This treatment is accompanied by hypodermic injections of strychnin, that are gradually increased in strength until toxic symptoms are produced. The dose is then to be diminished one-fourth, and so continued for several weeks. When there is an edematous or hyperemic papilla, potassium iodid may be substituted for the strychnin. When not otherwise contraindicated and the Turkish bath cannot be readily taken, the hot pack, combined with hypodermic injections of pilocarpin (gr. $\frac{1}{8}$) twice a week, is very useful, and certainly cuts short the duration of the amblyopia.

Lead-amblyopia.—Lead and its salts not infrequently produce amblyopia and amaurosis. These cases are most commonly found in painters, employés of paint- and lead-works, plumbers, as well as in persons poisoned from eating canned food or drinking water polluted with plumbic compounds.

The poison brings about so many changes in the brain and kidneys, as well as in the optic nerve, that it is often difficult to say whether the eye alterations are due to the direct action of the lead on the optic nerve, retina, and visual centers, or whether they are secondary to the other organic lesions. In any event, it is probable that the ocular changes *begin* in the terminal vessels of the eye as a fatty metamorphosis or obliterating endarteritis, and that subsequently the tissues supplied by these vessels undergo secondary metamorphoses.

These alterations affect the retina and papilla, and may be studied ophthalmoscopically. The commonest sign is *optic-nerve atrophy* with woolly disks and small vessels. Vision is always greatly affected, both at the center and

periphery. In another class of cases there is *optic neuritis*, with the usual appearances in and about the nerve-head; in still another a *retro-bulbar* degeneration sets in. Finally, there are states of *transient amblyopia* without ophthalmoscopic change; indeed, patients suffering from atrophy due to lead-poisoning often give a history of antecedent "attacks" of dim vision. These Gowers regards as analogous to the temporary amaurosis of diabetes and uremia, and thinks they are due to the direct effect of the lead salts upon the visual centers. In doubtful cases the excreta should be examined for lead. Oliver relates a case of progressive blindness where the urine, saliva, and nasal mucus revealed the presence of lead. In a case reported by the

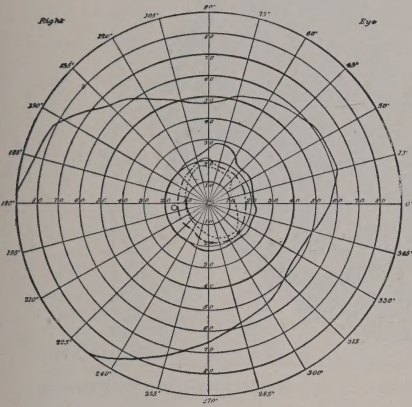


FIG. 271.—Visual field in lead-amblyopia.

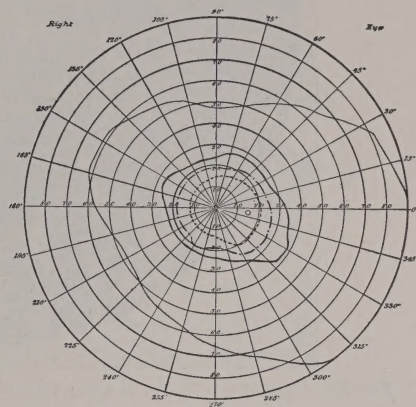


FIG. 272.—Visual field in lead-amblyopia.

writer there were marked optic-nerve atrophy, with restricted fields (see Figs. 271 and 272), and almost complete oculo-motor paresis on the left side.

Prognosis is favorable in the early stages of transient amblyopia, but very unfavorable when optic inflammation or atrophy has set in.

Treatment consists in the instant removal of the source of the poison, the administration of small doses of magnesium sulphate, the use of Turkish baths, and pilocarpin injections. Strychnin before a meal and potassium iodid after it are usually employed, but the former should be omitted when active inflammation is present.

Quinin-amaurosis.—Quinin, like lead, may be responsible for both a *temporary amblyopia* and an *amaurosis* with characteristic fundus changes. The blindness, in the latter instance, comes on suddenly, is often complete, and may last for several days. The pupils are widely dilated, and do not react to light, although they may to accommodation.

The ophthalmoscope shows an *absolute anemia of the fundus*. The papilla is chalky-white, and no trace of retinal vessels can be discovered. This remarkable condition is accompanied by other signs and symptoms of cinchonism, although permanent blindness is excessively rare. In severe cases the optic nerve rarely recovers entirely from the poisonous effects of the drug, and the patient henceforth exhibits decided limitations of the field (Fig. 273), often defective central vision, and usually evidences of retinal ischemia. Usually, large doses of the drug are required to produce amaurosis; but in some susceptible individuals even physiological doses have produced temporary blindness.

We are mainly indebted to Brunner and de Schweinitz for experimental proof that the amaurosis is due to a species of "edema of the optic-nerve

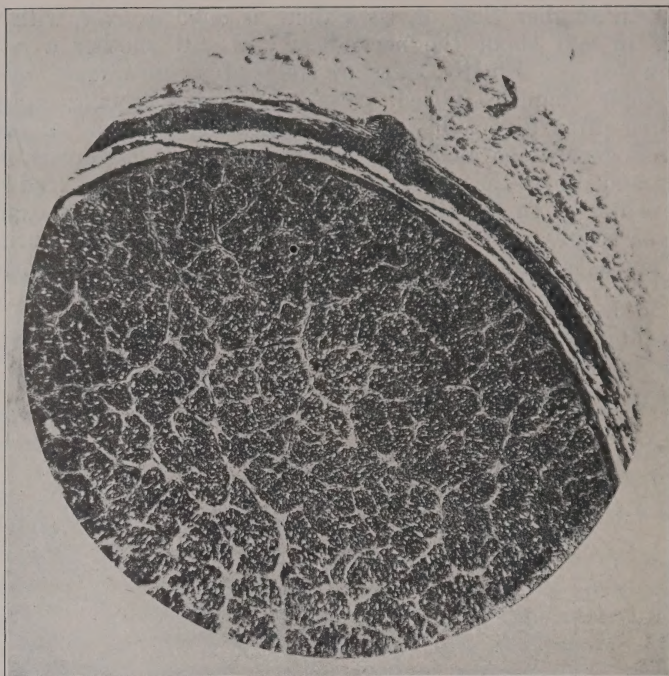


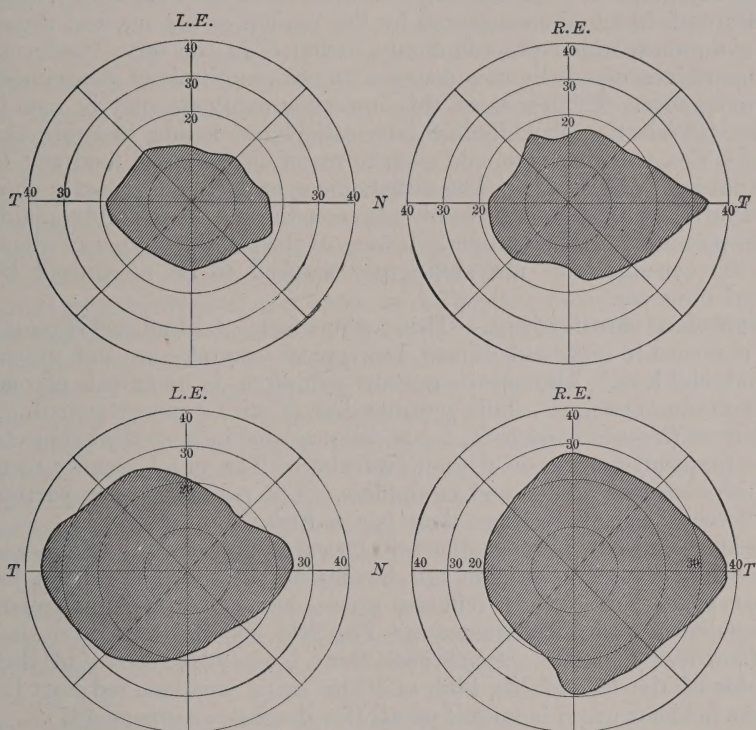
FIG. 273.—Normal optic nerve of a dog, transverse section; $\times 125$, Weigert stain (de Schweinitz).



FIG. 274.—Optic nerve of a dog blind from the effects of quinin, showing almost complete atrophy; $\times 125$, Weigert stain (de Schweinitz).

tissue between the chiasm and eyeball and the influence of quinin on the vaso-motor apparatus, which cause excessive constriction of the peripheral circulation, and finally local changes in the vessels (endovasculitis) and atrophy of the optic-nerve fibers" (Figs. 273 and 274). De Bono believes that quinin intoxicates the protoplasmic elements of the retina, acting as a depressant poison on the rods and cones. Holden has demonstrated that the *primary* action of the drug is upon the ganglion cells of the retina.

The treatment of quinin-amaurosis is much the same as that of tobacco-amblyopia. Nitrite-of-amyl inhalations give temporary relief.



FIGS. 275, 276.—Visual fields from Gruening's case. The shaded areas represent the limits of the fields, the upper map three and the lower one six months after recovery from complete blindness.

Ptomaïn-poisoning; Botulismus; Allantiasis.—The putrefactive alkaloids found in "high" game, decomposed sausage, uncooked meat, and rotten fish (as well as the leukomains of poisonous fungi, snakes, and shell-fish) occasionally produce amblyopia as one of the symptoms of intoxication. Brieger found *ethylenediamin* to be the active principle in several cases of poisoning from decomposed food.

Symptoms.—These closely resemble those of belladonna-poisoning; the dim vision is transitory, and it is uniformly due to bilateral paresis of accommodation with marked mydriasis. Ptosis is also a common symptom. All the extrinsic ocular muscles may be paralyzed, from bilateral and nearly complete ophthalmoplegia externa to paresis of a single muscle. There are no fundus changes. When death does not occur and the paralyzes persist, these are the result of basilar meningitis or nuclear hemorrhages. The treatment is the same as that suited to atropin-poisoning.

Male-fern amblyopia and amaurosis are not uncommon from acute poisoning with this drug, but the ocular symptoms (except that of blindness) and the fundus changes recorded have been far from uniform. Widely-dilated pupils, followed by optic-nerve atrophy, are most commonly observed. De Schweinitz and others have experimented on the lower animals with negative results; but Nuel and others have produced optic-nerve degeneration by administering extract of male-fern to animals.

Toxic Asthenopia.—Some time ago the writer ventured the opinion that the employment of certain intoxicants, some of them drugs and beverages in every-day use, is not infrequently followed by minor defects of vision, the true nature of which is unsuspected by the patient or his medical attendant. These symptoms, which are commonly included in the term "asthenopia," show themselves especially as a decrease in the amplitude of accommodation and convergence. Evidences of this muscular weakness may be seen in the transient intoxication from quinin, the salicylates, iodids, bromids, alcohol, tobacco, coffee, tea, chocolate, and such forms of decomposed food as "high" game, "strong" cheese, etc. The asthenopic symptoms occasionally observed in some forms of dyspepsia probably also constitute a toxic amblyopia due to ptomain-poisoning. They properly belong to those milder types of allantiasis where the eye-signs are not sufficiently marked to be recognized by the unskilled observer.

Hysterical Amblyopia.—This curious form of blindness is most commonly observed in girls and women, but typical examples are not unusual in men and children. The most constant symptom is amaurosis of one eye without fundus changes. This peculiar loss of visual power sometimes follows injuries (*traumatic hysteria, traumatic neurosis*) in hysterical subjects, but it more frequently comes on without warning. The pupil usually reacts to light, but it may be dilated and motionless. The patient is often partially or totally color-blind. Sometimes there is a central scotoma.

There are nearly always other hysterical symptoms present, especially hemianesthesia (usually variable and incomplete) of the affected side, loss of the pharyngeal and corneal reflexes, ptosis, monocular diplopia, micropsia and megalopsia and blepharospasm. *The field for red and green is often larger than that for white.* Sometimes there is *complete reversal* of the natural order of the color-fields, blue or white being smallest, red next in size, while the field for green is largest of all (for diagrams see page 487).

Diagnosis.—This is sometimes difficult, especially in recent cases. It is well known, for example, that the hysterical amblyope can be made to see. An instance of this occurred in a case known to the writer where an hysterical subject sued for damages on account of injury to the head causing blindness to the right eye. Malingering was set up as a defence, because it was shown that the patient saw with the supposed blind eye when examined by prisms and a light at twenty feet. In all cases of unexplained monocular blindness without fundus alterations hysteria should be suspected, and one should be on the lookout for its other manifestations.

Prognosis is favorable, but the amaurosis may persist for years. **Treatment** should be directed to the hysterical state generally. Electricity, massage, outdoor exercise, and tonics furnish the best results.

Pretended Amblyopia; Malingering.—It is comparatively easy to detect a pretended monocular amblyopia or amaurosis, but difficult to uncover the deception of the person who claims to be blind in both eyes. He may be exposed by watching him when he does not expect it, by flashing a bright light on his face, or by making feints to strike him, for the purpose of elicit-

ing the lid or iris reflex. As Swanzy points out, one cannot depend, for detection of the malingerer, upon the pupillary reactions, because the pupils contract to light, even when the patient is quite blind, if the lesion be situated at the cortical center or in the fibers that connect it with the corpora quadrigemina. Recently Priestley Smith and E. Jackson have suggested a simple test for feigned *binocular blindness*: Place a lighted candle in front of the subject; now hold a six-degree prism with its base to the temple before one eye; if both eyes see the one behind the prism will move inward, and on removing the prism will move outward, the other eye remaining fixed.

Many plans have been devised for the detection of simulated *monocular blindness*, but, on the whole, *Snellen's colored-letter test* for distant binocular vision is the most valuable. *The suspect should be watched that he does not close the alleged blind eye during the examination.* A frame holding transparent letters, colored alternately red and green and adapted to five or six meters' distance, is hung in a window or is highly illuminated from behind. A reversible spectacle-frame, fitted with a plane red glass on one side and a green glass on the other, is placed on the subject's face. The red letters can be distinguished only by the eye covered with the red glass (which shuts out the green rays), and the green letters can be read through the green glass only, because the red glass cuts off the green rays. If the subject reads red and green types with both eyes open, or during several trials, reads letters of a color that does not correspond with that of the glass in front of his admittedly sound eye, he must have seen with the alleged blind eye.

Dr. Harlan has suggested that a + 16 D. lens be placed before the eye acknowledged by the subject to be normal, and a - 0.25 D. sphere before the alleged blind eye. The suspect is now asked to read the ordinary distant-test types. If he succeeds, he is a malingerer, because the high-degree convex lens has made it impossible for him to see with the sound eye, and of course the weak concave glass does not interfere with vision. An additional control test may now be made by placing a book or a towel over the + 16 D. lens. The malingerer will declare his inability to read any of the letters, thus further exposing his attempted fraud.

Prism or diplopia tests are advised by some observers. The subject is seated before a point of light six meters distant. The supposed blind eye is covered with a frosted glass, and the apex of a 6° prism, directed up or down, is slowly advanced to the pupillary center of the sound eye, and the suspected person is asked to recognize the double images of the monocular diplopia thus produced. This maneuver is repeated, with the prism pointed in various directions, until he becomes accustomed to the idea of diplopia. A weak concave lens is now substituted for the frosted glass, and the suspect is examined by Stevens's phorometer or by simple prisms in the manner commonly advised for testing the extrinsic ocular muscles. If he now perceives double images, he must see binocularly, and may be pronounced a malingerer.

Snow-blindness.—This is a form of amblyopia produced by the blinding reflections of the sun upon the naked eye of persons (usually strangers) exposed to the brilliant snow-fields of northern latitudes or mountain-resorts. The dazzling at length causes contracted pupils and retinal congestion. Central and peripheral limitations of the field of vision have been observed, as well as a lessening of the visual acuity, especially for near work.

The most common effect of this exposure is, however, a peculiar form of *hyperemia* and *edema* of the conjunctiva. This is accompanied by swollen lids, lachrymation, burning pain in the eyeballs, photophobia, and blepharo-

spasm—symptoms attributed to “sun-burn” rather than to the effects of the light-rays. The writer has had occasion to study various grades of snow-blindness in Northern Canada and among the members of a party who spent some time on the Mer de Glâce.

The light-rays from electric furnaces and arc candles are capable of producing practically the same symptoms, constituting the so-called *electric ophthalmia*. Those who are much concerned with the Röntgen X-rays may suffer in a similar manner.

The eyes remain sensitive to light and show signs of retinal fatigue for some days, and the conjunctivitis may persist, requiring treatment proper to that condition. Rest in a darkened room, with atropin and hot applications, seems to give most relief to the retinal and corneal symptoms.

Erythropsia, or *red vision*, is most commonly seen after cataract extraction. It has also been observed in poisoning by santonin (which may also produce *xanthopsia* or *yellow vision*), and as a phosphene-experience in persons suffering from optic-nerve atrophy and glaucoma. These exhibitions of color may be due both to central irritation and to excitation of the retinal elements.¹ Potassium bromid has been recommended for this symptom. After cataract extraction patients often complain of a “glaring white haze” which seems to cover all objects. An uncommon phenomenon, described by Becker and Swan M. Burnett, is *kyanopsia*, or *blue vision*. According to the latter author, it is especially observed by patients with more or less amber-colored cataractous lenses, the blue appearance depending upon fatigue of the retina from long-continued exposure to yellow light, giving blue as a residual sensation in white light.²

Micropsia and Megalopsia.—In hysteria, in some diseases affecting the macular region, and after the correction of marked ametropia, objects may appear smaller or larger than usual, and these visual abnormalities are sometimes accompanied by distortion of the images. In the foregoing class of cases the rods and cones are either actually separated or pressed together as a consequence of retinal infiltration, or the contrast effect of corrected refractive errors may convey the impression of altered size. As Parinaud has shown, when these phenomena are experienced by hysterical amblyopes they are probably the effect of a variable accommodative spasm.

Night-blindness (*Functional Night-blindness*; *Hemeralopia*,³ preferably *Nyctalopia*).—This symptom is seen as a functional disturbance, probably due to diminished sensibility of the retina or rather imperfect adaptation-powers of the retina, unassociated with visible change in the background.

It has been observed as an epidemic affecting scorbutic soldiers and sailors who, in addition to insufficient feeding, have been exposed for a long time to the glare of the sun. Simeon Snell has seen it among the pupils of the English public schools. Among the poor and ill-nourished Russian peasants night-blindness has been frequently noticed, particularly during the fasts of Lent. It has been attributed to miasmatic influences by Adamück. Not only do nyctalopes see badly on dull or dark days and well on bright days, but they suffer from other ocular troubles, the chief of which is a peculiar wasting disease of the conjunctiva—xerophthalmia (see page 296).

The treatment of the condition that gives rise to the night-blindness is

¹ The reader will do well to consult Fuchs's paper on this subject in *Graefe's Archiv für Ophthalmologie*, Bd. xlii., abth. iv., or the review of it by W. Dudley Hall in the *Ophthalmic Record*, Feb., 1897.

² *Ophthalmic Record*, vii., N. S., 1898, p. 17.

³ See a discussion of the derivation, authoritative employment, and proper definition of these terms in the *Royal London Ophthalmic Hospital Reports*, vol. x. Part ii., June, 1881, p. 284.

called for—a generous diet, ferruginous tonics, cod-liver oil, hygienic surroundings, and protection from bright light.

Day-blindness (*Nyctalopia*, preferably *Hemeralopia*).—In almost all the forms of central amblyopia (see page 460) patients see best on dull days or in a dimly-lighted room. The explanation of this is that with a weak illumination the pupils are dilated, and most rays fall upon unaffected portions of the retina: bright light, on the other hand, contracts the pupils and the asensitive foveal region only is presented to objects. Persons from whom light has long been excluded exhibit this symptom, and it is said to be congenital in others.

Hemeralopia also occurs in retinitis nyctalopia, coloboma of the iris, and in albinism.

AMBLYOPIA OF THE VISUAL FIELD, SCOTOMAS, AND HEMIANOPIA.

BY H. V. WÜRDEMAN, M. D.,

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THE NORMAL FIELD.¹

The field of vision is that space perceived when the visual axis is directed to a stationary point. When both eyes are used the fields overlap, forming the binocular field or field of fixation (Figs. 277, 278).

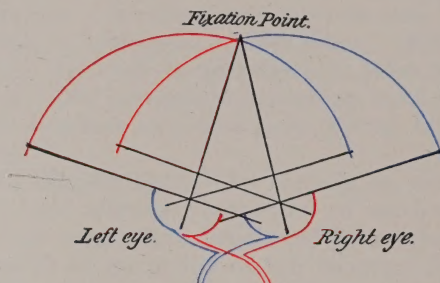


FIG. 277.—The binocular field of vision (after Foerster).⁴ The tracts from the right brain are in red, those from the left brain in blue. The corresponding retinal halves and their fields of vision are correspondingly colored.

The object fixed is within the range of direct vision, the rays of light falling directly upon the macula; those coming from surrounding objects fall upon other parts of the retina which have indirect vision. The visual acuity diminishes as images are removed from the macula to the periphery of the field. The normal field of vision is more or less constricted at the upper and nasal sides by the eyebrows and nose, forming the upper, inner, and lower limits of the field, the outer proceeding in normal eyes to a little beyond 90° from the fixation-point. Form and white are most eccentric, followed in order by blue, yellow, red, and green (Fig. 279). Overhanging eyebrows or a large nose materially limit the field. If the chart be improperly taken, as when the patient does not hold his head erect, does not fix the sight-hole of the perimeter, or nips the eyebrows or eyelids, variation may be found.

At the temporal side of the fixation-point from 10–20° is the physiologic *blind spot*, or *scotoma of Mariotte* (Fig. 279). By careful examination with very small test-objects other blind spots may be found which correspond to the places of division of the large retinal vessels. The physiologic scotoma may be larger or smaller according to the size of the nerve-head. In case of con-

¹ The field of vision has been fully discussed on page 99 and on pages 162–169; but for the convenience of the reader and to facilitate comparison with the abnormalities of the visual field which follow, a brief résumé of the subject is here introduced (Ed.).

tinuance of the medullary fibers of the disk the spot may be very large, including even the fixation-point (Figs. 280 and 296). As this is covered by

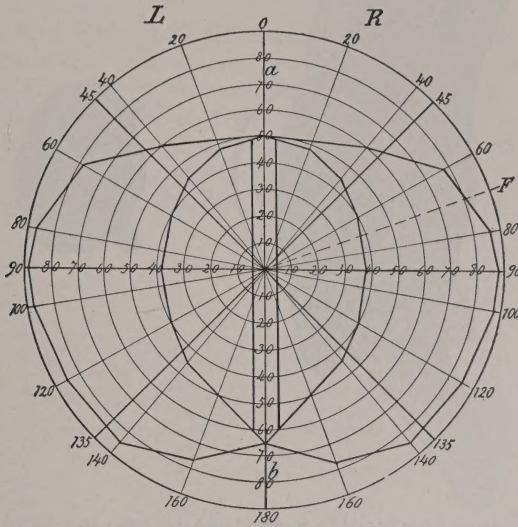


FIG. 278.—Binocular field of both eyes (after Knies):⁵ *L*, left, *R*, right half of the field of vision divided by the vertical line *a-b*, which passes through the point of fixation *F*. The vertical strip is the overlapping portion of the field of vision.

the visual field of the other eye in binocular vision, the existence of this spot is not noticed.

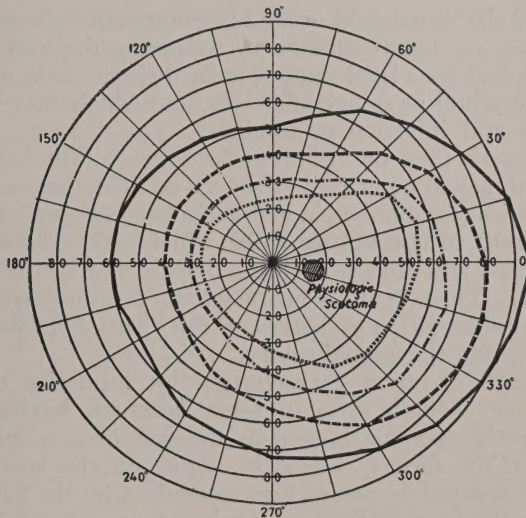


FIG. 279.—Diagram of normal field for form, white, and colors: The outer continuous line indicates the limit of the field for form and white, the dotted lines for the colors, blue, red, and green.

Although the fovea centralis is the point of best vision, yet astronomic observation has shown that feebly-reflecting stars are better seen when the vision is directed a little to one side, for the fovea is less sensitive to both

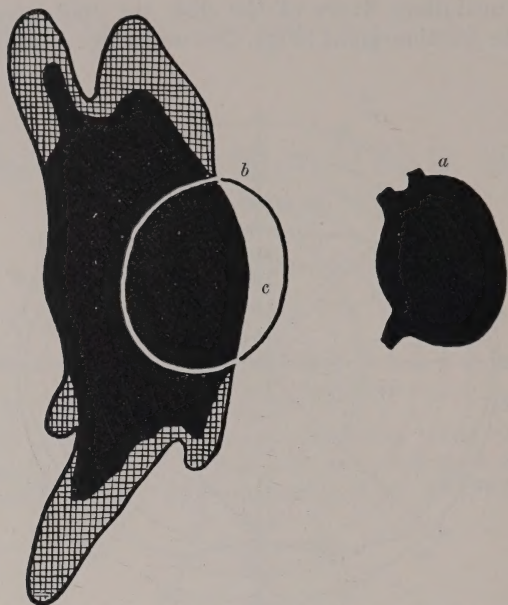


FIG. 250.—Physiologic scotoma (after Baas): ¹ *a*, normal blind spot (after Helmholtz); *b*, persistent opaque nerve-fibers; *c*, normal blind spot.

light and color in diminished light than the retina immediately surrounding it.¹

ANOMALIES OF THE VISUAL FIELD.

Anomalies of the visual field occur as symptoms of disordered conditions which themselves are manifestations of well-recognized affections, such as diseases of the eye, of the visual centers, or of their connections, which may be due to trauma, cerebral or spinal affections, and which may in their turn be part of some general infection or condition.

Besides *amblyopia* (loss of vision) and *amaurosis* (blindness), which occur in connection with actual anomalies of the visual field, there exist two distinct groups of anomalies (for *amblyopia* and *amaurosis*, see page 457).

I. Contraction of the visual field, which may be *regular* (concentric), *irregular* (eccentric), and *sectoral*. These defects may be due to local as well as central lesions. There is also a characteristic form occurring in both eyes, with symmetrical obliteration of halves of the visual field—true *hemianopia*—due to lesion within the cranial cavity.

II. Scotomata, a group characterized by formation of scotomata or blind spots in one or both eyes, in some instances having a hemianopic aspect. The *positive* scotoma is seen by the patient as a dark or black spot upon objects. In the former case it is *relative*, in the latter *absolute*.

The *negative* scotoma is not at first recognized by the patient, but is developed through the examination. A typical example of this is the normal blind spot. The scotoma may occupy various positions, be single or multiple, central, para- or pericentral, or may have a circular form, the so-called ring scotoma (see also page 169).

The special affections of the organ of vision in which anomalies of the visual field occur are—

I. Optic hindrance in the refractive media; II. Diseases of the retina;

III. Diseases of the choroid; IV. Glaucoma; V. Diseases of the optic nerve; VI. Diseases of the chiasm; VII. Diseases of the optic tract from the chiasm to the visual centers; VIII. Functional diseases and nerve-lesions of different kinds.

Changes in the Visual Field due to Optic Hindrance.—Foreign bodies or opacities in the cornea, lens, vitreous (Fig. 281), or outer layers of the retina may be attended by obscuration of vision through optic hindrance, and cause amblyopia, contraction of the visual field, and scotoma.

Trauma of the eyeball may be followed by either destruction of tissue and bleeding, or both, causing changes in the visual field. Pre-retinal hemorrhage causes diminution of the visual field and absolute or relative scotoma (Fig. 282).

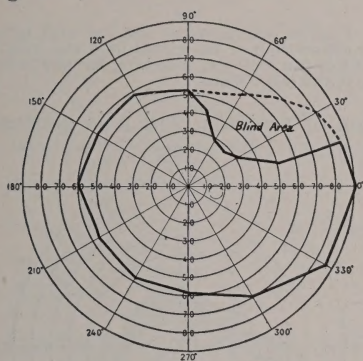


FIG. 281.—Sectoral contraction due to pre-retinal hemorrhage and foreign body in vitreous after injury by gunpowder explosion.

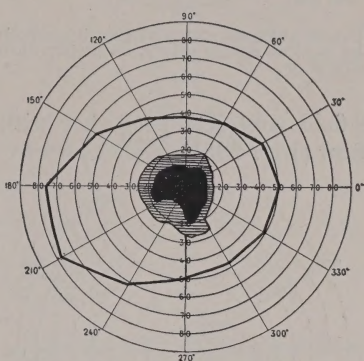


FIG. 282.—Central absolute and relative scotoma due to retinal hemorrhage in congenital syphilitic chorio-retinitis.

Changes in the Visual Field in Diseases of the Retina.—

Changes in the nutrition of the retina and choroid, such as occur in night-blindness, produce amblyopia, which is especially noticeable in diminished light, together with contraction of the visual field, particularly noticeable for blue⁶ (Figs. 283 and 284 (see also page 468)).

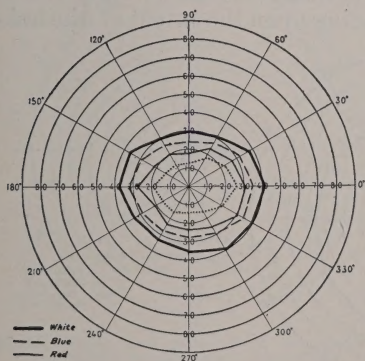


FIG. 283.—Concentric contraction in chronic night-blindness.

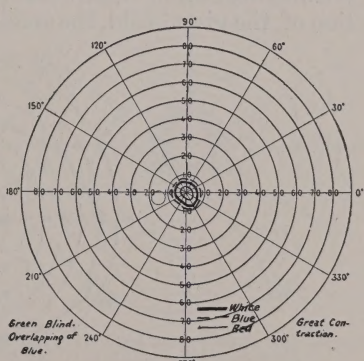


FIG. 284.—Great concentric contraction with overlapping of blue field, and green-blindness in chorio-retinitis pigmentosa, with nyctalopia.

Embolism of the central artery of the retina and *thrombosis* of the central vessels give rise generally to amaurosis, proceeding to complete blindness, but where the blood-stream is not completely cut off the vision is diminished and

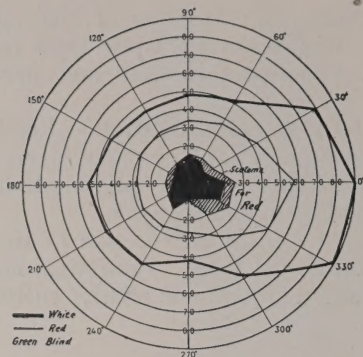


FIG. 285.—Central scotoma in partial embolism of the central retinal artery, occurring during menstruation.

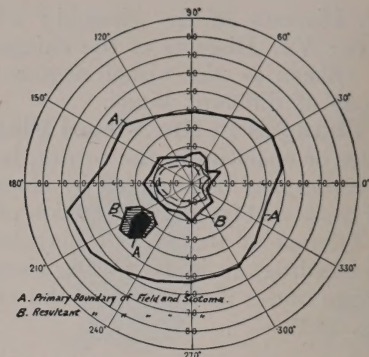


FIG. 286.—Para-central scotoma with secondary contraction of the visual field and enlargement of the scotoma, following foreign body in the retina (after Baas).¹

the field contracted, together with formation of scotoma, which is generally central (Fig. 285).

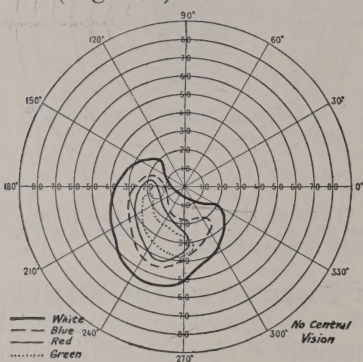


FIG. 287.—Typical constriction of field due to peripheral detachment of the retina.

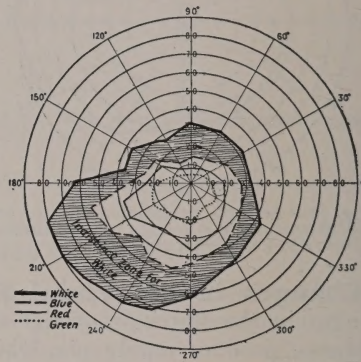


FIG. 288.—Typical contraction of visual field due to circular detachment of the retina.

Hemorrhages into the retinal structure produce scotoma or irregular contraction of the visual field, the amount depending upon the extent of the lesion.

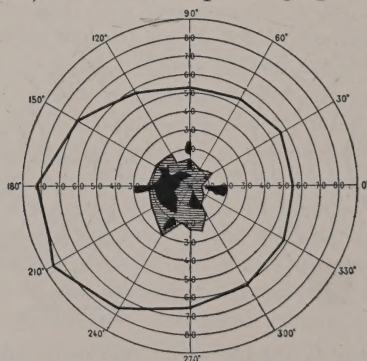


FIG. 289.—Absolute and relative para- and pericentral scotomata in neuro-retinitis albuminurica occurring during pregnancy.¹⁸

Foreign bodies in the retina cause scotoma (Fig. 286).

Detachment of the retina from traumatism or in myopia is attended by characteristic defects according to its extent (Figs. 287, 288).

Retinitis albuminurica,¹⁸ *diabetica*, and *circinata* are attended by scotoma (Fig. 289), usually central, and are followed in their retrogressive stages by atrophy of the retina and nerve, with amblyopia or amaurosis and contraction of the visual field.

Changes in the Visual Field in Diseases of the Choroid.—

Circulatory disturbances and changes in the nutrition of the choroid produce characteristic changes (Figs. 290, 291). Coloboma of the choroid is attended by sectoral defects and usually scotoma (Fig. 290). Rupture, hemorrhage, and tumor²¹ of the choroid give rise to defects depending upon the extent of the lesion (Fig. 291).

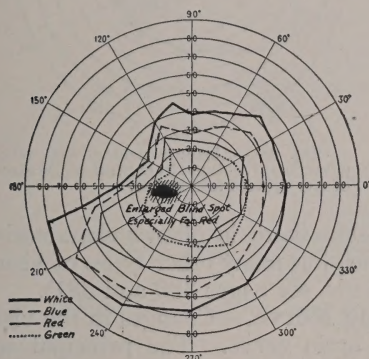


FIG. 290.—Sectoral contraction of the visual field and enlarged blind spot due to typical coloboma of the choroid and staphyloma posticum.

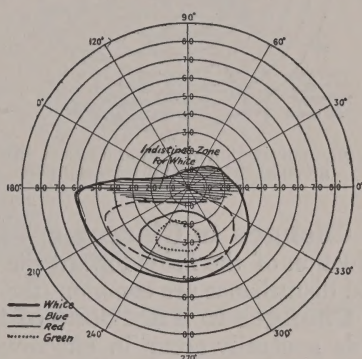


FIG. 291.—Sectoral contraction of the visual field simulating vertical hemianopia in sarcoma of the choroid.²¹

Choroiditis, especially the exudative form, usually causes multiple scotomata (Fig. 292) which are absolute or relative. By their coalescence larger scotomata are formed which may even take a peculiar ring form (Fig. 293). The visual fields may likewise be greatly reduced. If the choroiditis be at the macula, central scotoma will be developed.

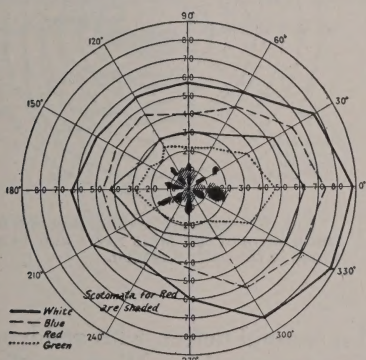


FIG. 292.—Para- and pericentral scotomata in exudative disseminated choroiditis.

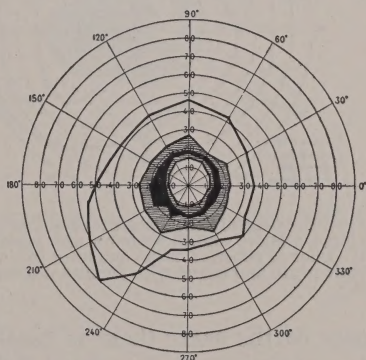


FIG. 293.—Absolute and relative ring scotoma in syphilitic chorio-retinitis.

Chorio-retinitis pigmentosa is usually attended by great contraction of the visual field and amblyopia (Figs. 294, 295). In myopia staphyloma posticum may develop, and the blind spot be rendered abnormally large thereby, so that it may even extend to the fixation-point. In senile atrophy of the choroid central scotoma and reduction of the visual fields, with am-

blyopia, result (Fig. 295), the shape of the scotoma bearing a relation to the shape of the atrophic area.

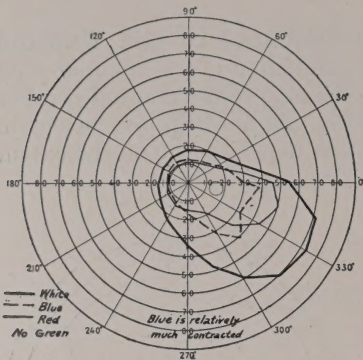


FIG. 294.—Contraction of field and loss of vision for green in chorio-retinitis pigmentosa.

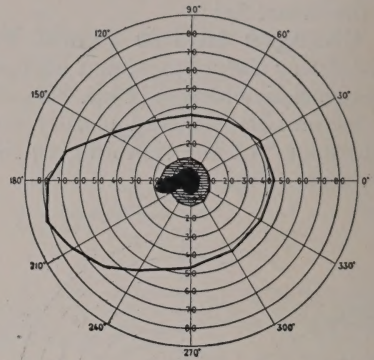


FIG. 295.—Absolute central and relative paracentral scotoma in central senile atrophy of the choroid and retina.

Changes in Glaucoma.—In glaucoma there is often a characteristic reduction of the fields toward the nasal side; but many other types of visual-field disturbance are common (for visual fields, see pages 380 and 381).

Changes in Affections of the Optic Nerve.—Changes in the visual fields generally occur in affections of the optic nerve. The principal congenital defect is coloboma of the nerve and its sheath, and is attended by enlargement of the blind spot (Fig. 296).

In traumatism with rupture or bleeding into the nerve (Fig. 297) and in

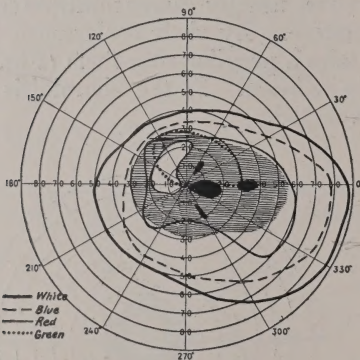


FIG. 296.—Central and paracentral absolute scotomata, with large relative central scotoma and preservation of small sector of superior nasal quadrant in coloboma of the optic nerve and retina with persistent opaque nerve-fibers.¹⁷

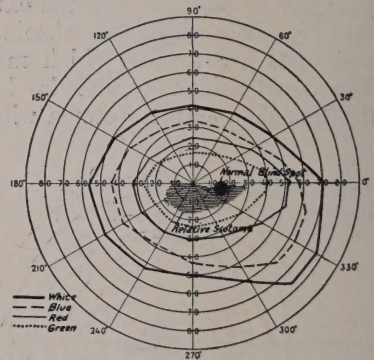


FIG. 297.—Relative sectoral scotoma from traumatism of the optic nerve and hemorrhage in the optic foramen.

tumors of the nerve there is usually found a sectoral defect, with amblyopia and contraction of the visual field resulting in atrophy. Diseases affecting the intraocular end of the optic nerve, such as papillitis, cause decided changes in the visual field, depending upon the amount of optic interference caused by the swelling and bleeding into or destruction of the nerve-tissue. The blind spot is usually much enlarged¹⁷ (Fig. 298). The relation between the ophthalmoscopic appearances and the visual acuity is frequently not commensurate. These cases usually terminate in atrophy with contraction or sectoral defect and scotomata.

Retro-bulbar neuro-retinitis, or *toxic amblyopia* is usually attended by central scotoma due to implication of the axial fibers. (It is fully discussed on page 461.)

Atrophy of the Optic Nerve.—Many cases coming under the foregoing result in sclerotic changes in the optic nerve. However, it is known that a

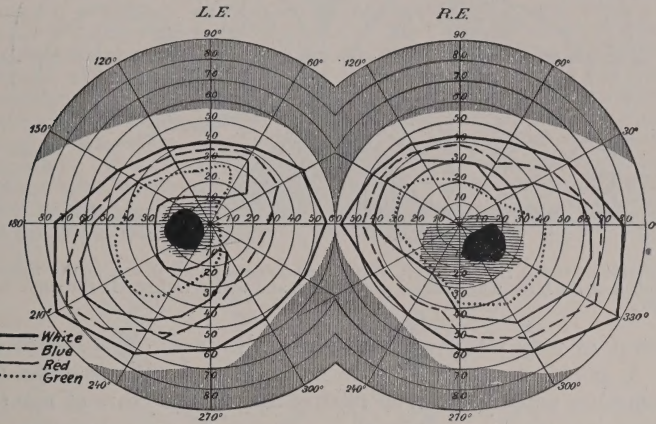


FIG. 298.—Visual fields in papillitis, due to gumma at the base of the brain, showing great enlargement of the blind spots.

large proportion of cases with diminished vision, due to atrophy of the nerve-fibers, are associated with sclerotic changes in the spinal cord. Among these is atrophy due to tabes, which in many instances is a premonitory sign of this disease.¹⁰ Various forms attended by non-characteristic changes in the visual field occur in multiple sclerosis, progressive paralysis, syringomyelia, amyotrophic lateral sclerosis, exophthalmic goiter, cerebral syphilis, degenerative changes, and different mental diseases.¹

The visual field in optic-nerve atrophy is usually constricted, and the contraction for color greater than that for form and white (Fig. 299). The

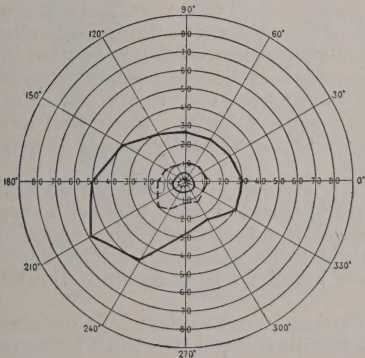


FIG. 299.—Contraction of the field especially marked for color occurring in secondary atrophy after syphilitic neuro-retinitis.

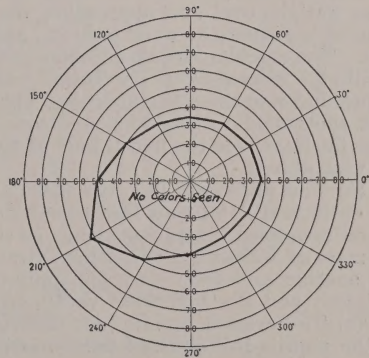


FIG. 300.—Moderate contraction in tabetic atrophy with abolition of the color-sense.

color-sense may be entirely absent, and yet the field be of moderate extent (Fig. 300). Scotomata may appear. The atrophy and consequent loss of sight may proceed for a while (*stationary optic-nerve atrophy*), and then

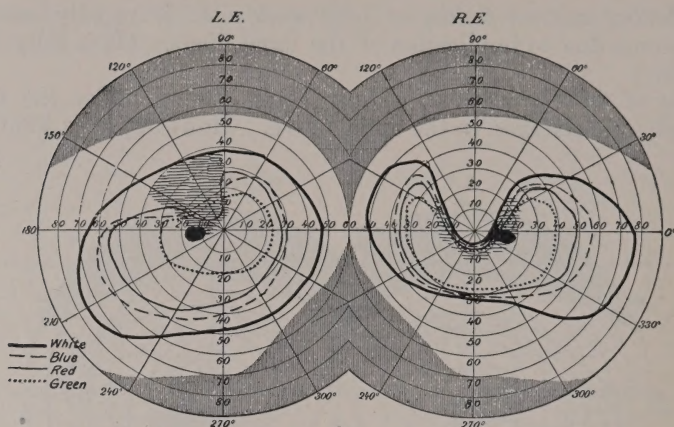


FIG. 301.—Fields of vision in hereditary atrophy showing sectoral defect of the right and relative scotomatous defect of the left. The latter is progressing and will terminate in the same form of field as that of the right.

definitely stop, or may progress to absolute blindness (*progressive optic-nerve atrophy*). A peculiar progressive form associated with scotoma (*hereditary atrophy*) comes on usually between twenty and thirty years of age (Fig. 301).

THE VISUAL PATHWAY.

The visual tract or pathway (see Fig. 302) proceeds from the retina to its final termination in the brain, the separate subdivisions of nerve-fibers lying in different relations at different portions of its course.

The peripheral percipient elements in the retina are the rods and cones, which are connected by fibers with the outer and inner granular layers, which in the region of the macula lutea are very fine and anastomose freely, and cannot, as elsewhere, be separately traced. The anatomic relations of the optic nerve-fibers, as given by Henschen and described by Wilbrand,²³ are as follows:

(a) The macular bundle lies ventro-laterally in the papilla and also immediately behind it. At the latter place it forms a keystone-shaped sector, with its base turned toward the pial sheath and its point toward the central vessels.

Farther back this bundle is halfmoon-shaped. Still farther back it takes the form of an upright oval and approaches nearer the axis of the optic nerve. In the optic foramen it assumes an axial position, and in front of the chiasm the form of a horizontal oval. The macular bundle contains crossed and uncrossed nerve-fibers. In front in the papilla the crossed fibers lie ventrally and the uncrossed ones more eccentrically, being in proximity to the other uncrossed fibers. The fibers spread over the retina. Farther back the macular fibers become drawn together toward the center. The dorsal half of these fibers goes to the dorsal half of the retina, whilst the ventrally-placed fibers go to the ventral half.

(b) The uncrossed (not the macular) bundle is divided in the anterior division of the optic nerve into two fascicles—a dorso-lateral uncrossed dorsal part and a ventro-lateral uncrossed ventral portion. In the lamina cribrosa these fibers are separated by the macular bundle. Behind the entrance of the central vessels the fascicles approach one another and form a united halfmoon-shaped bundle, which includes the lateral periphery and lies somewhat ventro-laterally.

(c) The crossed bundle (not macular) forms a closed cord in the whole optic nerve. In the papilla it is situated dorso-medially, and retains this position until it passes the chiasm.

The papillo-macular bundle, which reaches the chiasm in the shape of an oval lying horizontally, retains its central position until it reaches the chiasm. Farther back toward the center of the chiasm it almost reaches the periphery, and here the fibers belonging to the fasciculus cruciatus cross one another. It sinks once more and lies ventro-centrally in the tract. The crossed fibers of this bundle lie more centrally, and the uncrossed ones more laterally.

When a cross-section of the optic tract is made immediately in front of the chiasm,

it will be found that the crossed fibers occupy the dorso-medial part of the periphery of the section, and the uncrossed fibers are situated in the ventro-medial portion of the periphery of the section. The bundles then become divided into a number which are flattened horizontally, and these intermix with one another. The crossed fiber-bundles come together again at the ventro-lateral margin of the chiasm, forming the tract. Then there is a displacement. The crossing does not take place all at one point, but the dorsal nerve-fiber bundles first cross, followed by the more centrally-situated ones. At the posterior angle of the chiasm the commissural nerve-fibers, described by von Gudden, Meynert, and Forel, which have no influence on vision, are found.

The macular bundle courses centrally in the tract. The uncrossed bundle lies dorso-laterally, forming a close cord. The bundles retain this position until they enter the corpus geniculatum, where they separate into a mass of separate fibers. The crossed bundle lies ventro-medially, and forms a bundle which lies slantingly and hangs loosely together.

The *tractus* winds around the *crus cerebri*, and terminates in two roots upon the *corpora geniculata externa* and *interna*, and upon the posterior part of the *optic thalamus*, called the *pulvinar*. Fibers also go to the anterior part of the *corpora quadrigemina*, but these organs are not regarded as concerned in vision, but in the activity of the pupil. The parts just referred to are called the *primary visual ganglia*, or *primary optic centers*.

In them are found innumerable ganglion-cells in which the fibers of the tractus lose

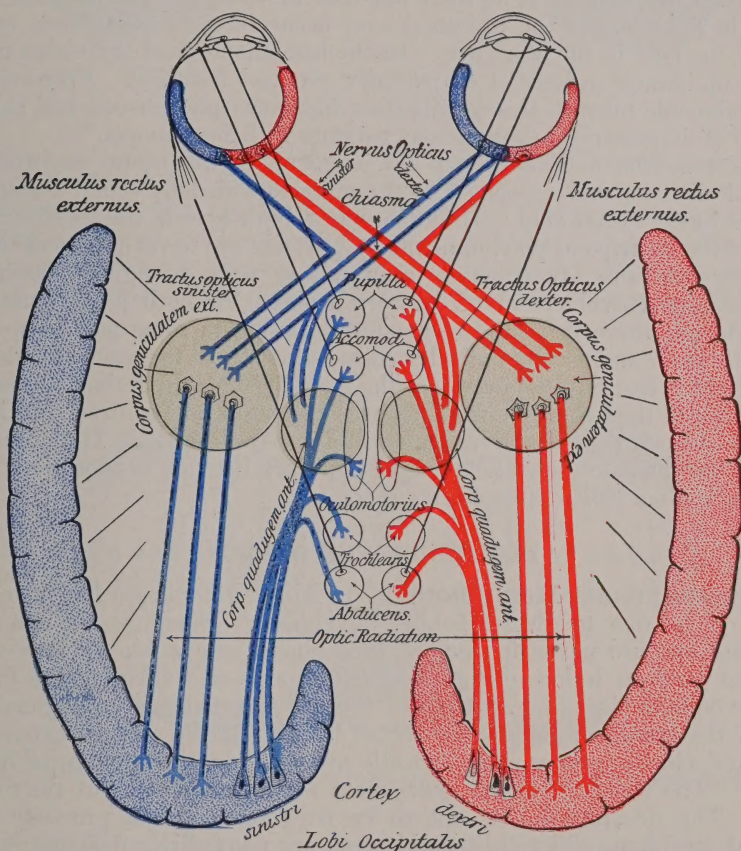


FIG. 302.—Scheme of the optic tract (after von Monakow).⁴

themselves, and thereafter a new set of fibers proceeds backward through the posterior part of the internal capsule to the cortex, under the name of the *visual radiations*, or *fibers of Gratiolet* or of *Wernicke*. Passing through the internal capsule, they cross the sensitive fibers coming down from the hemisphere, are rather closely massed, and then, spreading out like a fan, rise upward, wind outside the tip of the lateral ventricle to reach their destination at the lower part of the median surface of the occipital lobe (Fig. 302).

DISEASE WITHIN THE CRANIUM.

Diseases of the brain affecting the optic nerve or tracts give rise to characteristic lesions. Optic neuritis is common, although not a constant symptom of brain-tumor. It is attended by changes in the visual field, already described.

Hemianopia or Hemianopsia.—Hemianopia, or half-blindness of the visual field, resulting from a localized cause, is common to both eyes. If the obliterated half be toward the same side in both eyes, it is called *homonymous* (lateral hemianopia); if the opposite sides be affected, it is called *heteronymous* (nasal or temporal). The term hemianopia should be limited to half-blindness affecting *both* eyes.¹ Sectoral defects simulating hemianopia may arise in one or both eyes (Figs. 281, 287, 290, 291, 297) from diseases of the optic nerve or retina, but are not to be considered in this connection.

The hemianopia may include half of the fields (*complete*), or affect sectors (*incomplete* or *partial*), or involve one-half of the field on one side and a sector in the other, or the blindness may occur in the whole of one eye and part of the field in the other eye. In the hemianopic field the vision may be totally obliterated (*absolute*) or partially retained (*relative*). Pressure upon the hemianopic sides of the eyeball does not cause phosphenes, and this fact may be of importance in cataractous patients with hemianopia.⁸

The *condition and reaction of the pupils* are of diagnostic importance in cerebral diseases, and especially in those accompanied by ocular lesions and changes in the visual field. Illumination of both eyes in uncomplicated diseases of the centripetal portion of the optic-reflex arc never produces unequal pupillary reaction. Both pupils may fail to react to light, though sight remains good (involvement of Meynert's fibers), or both pupils may react alike, though there be complete amaurosis (lesion in some part between the Gratiolet fibers and psycho-optical cortical center).² In the case of hemianopia, when light is cast into the eye upon the seeing side of the retina, if the lesion be anterior to the primary optical ganglia, the pupil will contract, but if light is directed upon the blind side there will be no contraction. If the lesion be beyond the thalamus, such hemianopic pupillary inaction cannot occur. This reaction is often called *Wernicke's symptom*.

DISEASE OF THE CHIASM.

Heteronymous Hemianopia.—1. *Nasal hemianopia* has never been shown to be due to disease behind the chiasm.³ Since these fibers do not decussate and are never in contact, it is almost impossible to conceive of a bilateral cerebral lesion of the same extent and size affecting the function equally on both sides (Fig. 303). In the few reported cases a bilateral affection of the trunks of both optic nerves in front of the chiasm, extending to these and chiefly intense symmetrically at each side, has been found or diagnosed.³ The visual fields are obliterated at the nasal sides of the fixation-point. The dividing-line is apt to be irregular and not precisely in the vertical meridian. The obliterated areas are not entirely deficient in light-perception, and there is hemianopic pupillary inaction. Usually evidences of inflammatory changes will be seen on ophthalmoscopic examination in disturbances of circulation, swelling, or hemorrhages on the disk, followed later by atrophic changes. Disturbance of vision as regards walking about is not very great.

2. *Temporal hemianopia* (Fig. 304) is caused by disease of the chiasm where the decussating fibers of both tracts interweave. The visual fields are

obliterated at the temporal side of the fixation-point. The dividing-line is usually irregular and the blind areas may retain some perception of light. Hemianopic pupillary inaction is present. Ophthalmoscopic examination is usually negative except in the later stages, when atrophy of the optic nerve

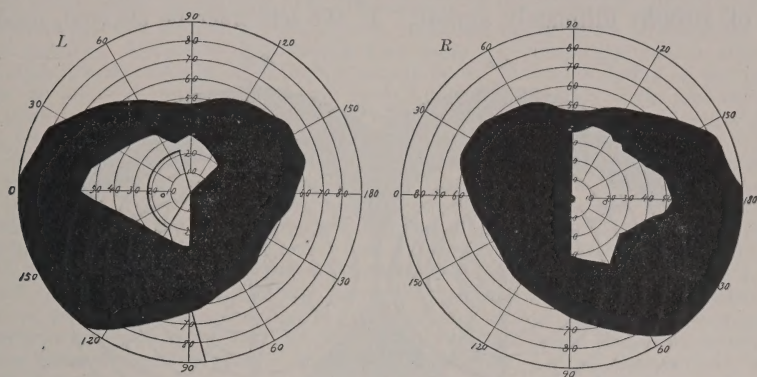


FIG. 303.—Nasal hemianopia (after Veasey).¹⁴

may occur. Disturbance of the vision is great, as the patient may only see directly ahead and has difficulty in orientation.²⁰

Diseases of the Optic Tract from the Chiasm to the Visual Centers.—*Lateral or homonymous hemianopia* is due to disease affecting the optic tract behind the chiasm. Corresponding sides of the visual fields are affected (Fig. 305). The dividing-line between the seeing and the blind

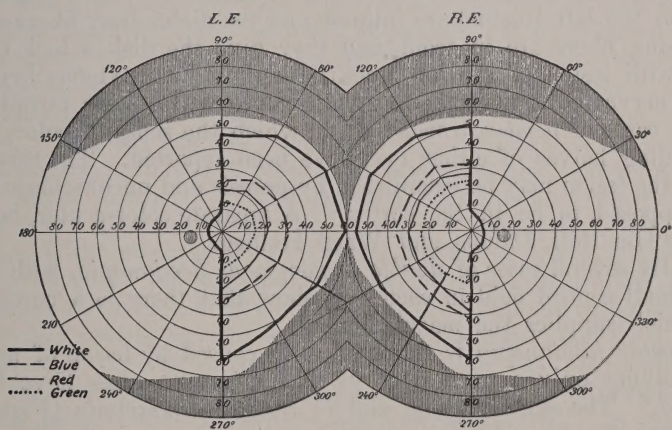


FIG. 304.—Temporal hemianopia occurring after hemorrhage at the optic chiasm, with preservation of central vision.

areas is usually well defined, running perpendicularly through the fixation-point, the visual acuity and color-sense being normal up to the edge of the obliterated area, the hemianopic field having no perception. In many it will be found that the central vision has either remained or is entirely obliterated, this being due to the fact that the macula in these cases receives fibers through both optic tracts (also proved by the occurrence of double hemianopia),¹⁰ and if the field be carefully taken it will be found that there is a bulge in the line of demarcation between the hemianopic and the seeing field. If the

fixation-point lies in the obliterated field, there will be central blindness; if in the remaining field, the central vision will remain. Right-sided hemianopia causes more disturbance than left-sided, as we read from left to right.⁴ Patients see and walk fairly well by turning the head to one side.

At first no lesion will be found on ophthalmoscopic examination, although signs of atrophy ultimately appear. If the left tract be affected, producing

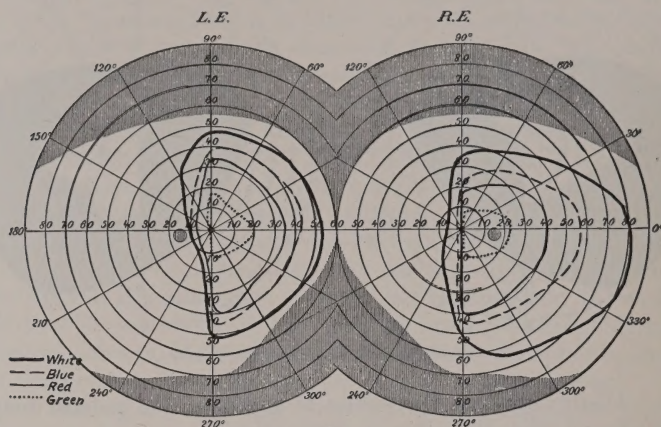


FIG. 305.—Lateral hemianopia occurring in multiple sclerosis.

right hemianopia, the right optic nerve will in time become wholly atrophic, and the left optic nerve look normal for the reason that in the left eye the tract-fibers are diminished and the crossing fibers are good; the former are covered by the whole of the disk. In the right eye the crossing fibers (derived from the left tractus) are injured and the direct-tract fibers are sound. The crossing fibers are in front, and they give the disk a look of general atrophy, with lesion of the left tract (with right homonymous hemianopia). The left nerve looks normal; the right nerve will appear atrophic.⁷

A few cases of *hemi-achromatopia*, in which the sense of color is lost for corresponding halves of either eye, have been reported. The cerebral character of the lesion may be established by paresis and unconsciousness. The site is supposed to be in the cortex.⁸ A separate color-center, however, is denied by Ole Bull, Dahms, and Ward Holden.

Recently several cases of *double homonymous hemianopia*, with preservation of small central field in each eye, show that there is a cortical visual center which supplies the macula lutea.⁴

Monocular hemianopia is supposed to be caused by lesion of part of one tract involving only a portion of its fibers, but no cases have been well established.⁴ The same may be said of *vertical hemianopia* (Figs. 291 and 297). Many diseases of the nerve and retina simulate a hemianopic field, but cannot be considered under the classical definition. The causes of the three varieties of hemianopia include traumatism, hemorrhages, embolisms, periostitis, tumors, softening and sclerosis of that portion of nerve lying within the skull.

The Significance of Hemianopia.—Hemianopia is not in itself a localizing symptom. There are usually other symptoms which assist in the diagnosis. Seguin's rules are as follows:

"1. Lateral hemianopia always indicates an intracranial lesion on the opposite side from the dark fields. 2. Lateral hemianopia with pupillary immobility, optic neuritis, or atrophy, especially if joined with symptoms of basal disease, is due to lesion of one

optic tract or of the primary optic centers of one side—*i. e.* the corpora quadrigemina and parts included within primary optic centers (including corpora quadrigemina, corpora geniculata, and pulvinar of the thalamus opticus) (Fig. 306). 3. Homonymous sector-like defects of the same geometric order, with hemianesthesia and choreiform or ataxic movements of one-half of the body, without marked hemiplegia, are probably due to lesion of the caudo-lateral part of the thalamus or of the posterior (caudal) portion of the internal capsule, fasciculus opticus, and radiating visual fibers of Gratiolet in the internal capsule. 4. Lateral hemianopia with complete hemiplegia (spastic after a few weeks) and hemianesthesia is probably caused by an extensive lesion of the internal capsule in its knee and caudal part (pulvinar)—*i. e.* farther back and more profound than in supposition 3. 5. Lateral hemianopia with typical hemiplegia (spastic after a few weeks)—aphasia if the right side be paralyzed and with little or no anesthesia—is quite certainly due to occlusion of the middle and adjacent cerebral arteries with extensive superficial lesion, softening of the motor zone and of the gyri lying at the extremity of the fissure of Sylvius—*viz.* the inferior parietal lobule, the supra-marginal gyrus, and the gyrus angularis. There may also be alexia, word-blindness. 6. Lateral hemianopia with moderate loss of power in one half of the body, especially if associated with impairment of the muscular sense, would probably be due to a lesion of the inferior parietal lobule and gyrus angularis with their subjacent white substances, penetrating deeply enough to sever or compress the optic fasciculus on its way posteriorly to the visual center. If mental blindness exists, the lesion would lie in the more anterior central parts of the occipital lobe. 7. Lateral hemianopia, without motor or common sensory or any accompanying symptom, is due to lesion of the cuneus only, or of it and the gray matter immediately surrounding it, on the mesial surface of the occipital lobe in the hemisphere opposite the dark half-fields. The lesion may be partial or total. Most surgical cases come at once or after convalescence within this rule or within rule No. 6. In all cases coming under rules 3 to 7, inclusive, the pupils react normally, and rarely does the ophthalmoscope show any lesion of the optic nerve, except, of course, in some tumor cases, where neuro-retinitis may be expected.”¹²

Amaurosis Partialis Fugax (*Transient Hemianopia*).—*Flickering scotoma* is a form of temporary blindness of a hemianopic character usually associated with unilateral migraine, which is accompanied by malaise, vertigo, and sometimes disturbances of memory or speech. It is supposed to be due to disturbance of the circulation from spasm in the vessels of the brain, and, when accompanied by headache, in those of the dura mater.¹ A typical attack usually begins with a dark spot in both eyes in the same part of the visual field. This spreads, but remains in the nasal half of one visual field and the temporal left of the other. Silvery flickering points or shadows move in a zigzag manner. Part of the dark spot extends toward the end of the visual field. The blindness usually lasts a quarter to a half hour and disappears. If the visual field be examined during the attack, a defect will be found. In one case¹³ the scotoma appeared as in the illustration (Fig. 306), growing larger and larger, finally obliterating the object and then disappearing. In another case¹ central scotoma with loss of light-, color-, and form-sense was found. In only one case in the writer's experience has this condition been associated with hysteria, the others happening in persons of nervous organization whose general state of health was somewhat lowered. In one case,⁹ of a physician who was subject to the flickering scotoma, an attack was followed several weeks later by hemianesthesia, hemiplegia, and death with bulbar symptoms. At the autopsy the right vertebral artery was found thrombosed and obliterated. In this case the “flimmer scotom” was certainly due to disturbance of the circulation.

The *scotoma scintillans* of Listing is a peculiar subjective visual sensation of the same character. In some cases there is a kind of after-image of the true scotoma appearing at night or in dim light, lasting but half an hour, which consists in a rapid succession of luminous figures with dark intervals. In one case²² these appeared in the upper right quadrant of the binocular field as a glittering figure quite close to the fixation-point, of an irregular;

crescentic shape, increasing for a while and gradually receding from the center of the field, growing larger and dimmer and finally fading away. Reading was not materially interfered with.

I remember, I remember, the house where I was born;
The little window where the sun came peeping in at morn.
He never came a wink too soon, nor brought too long a day,
But now I often wish the night had borne my life away.
I remember, I remember the fir trees dark and high;
I used to think their very tops were close against the sky
It was in childish innocence, but now 'tis little joy
To know I'm farther off from Heaven than when I was a boy.

2
I remember, I remember the house where I was born,
The little window where the sun came peeping in at morn.
He never came a wink too soon, nor brought too long a day
But now I often wish the night had borne my life away.--
I remember, I remember the fir trees, dark and high;
I used to think their very tops were close against the sky
It was a childish innocence but now 'tis little joy,
To know I'm farther off from heaven than when I was a boy.

3
I remember, I remember the house where I was born
The little window where the sun came peeping in at morn.
He never came a wink too soon, nor brought too long a day,
But now I often wish the night had borne my life away.--
I remember, I remember the fir trees dark and high;
I used to think their very tops were close against the sky
It was in childish innocence but now 'tis little joy,
To know I'm farther off from heaven than when I was a boy

4
I remember, I remember the house where I was born;
The little window where the sun came peeping in at morn.
He never came a wink too soon, nor brought too long a day,
But now I often wish the night had borne my life away.
I remember, I remember the fir trees dark and high;
I used to think their very tops were close against the sky
It was in childish innocence but now 'tis little joy,
To know I'm farther off from heaven than when I was a boy.

5

too soon
the night

6

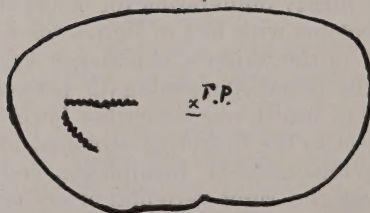


Fig. 306.—Appearance of printed page in amaurosis partialis fugax (after Stirling). (13)

Treatment of this condition consists in restriction from brain-work, regulation of diet and daily life. The administration of antipyrin, phenace-

tin, or caffein may cut short the duration of the attack and relieve the symptoms. Bromid of potassium and quinin have been advised.

FUNCTIONAL DISEASES.

(*Retinal Anesthesia; Neurasthenic Asthenopia; Hysteric Amblyopia.*)

Anesthesia of the retina (see also page 410) is characterized by reduction of the visual acuity and concentric contraction of the visual field or other changes, together with functional disturbances in other parts of the body.

It occurs for the most part in anemic women who are often the subjects of uterine and ovarian disease or chlorosis, or in children at puberty; occasionally cases are seen in young men. The loss of sight is usually partial, although it may be total, and in some cases the apparent loss is heightened by malingering. It is purely an hysteric manifestation, and as such may last from a few hours to days, weeks, or months. Indeed, patients have been known to shut themselves up in dark rooms for a long time, especially if attended by sympathizing friends or relatives. The subjects usually complain of considerable eye-pain, dazzling and photophobia, headache, and blindness by artificial light, haziness, dimness of letters and lines on reading, lachrymation, and occasional diplopia.

The *causes* of the condition are over-exertion at school or over-work, traumatic neurosis from injuries which are often trifling, general ill-health, and diseases of the genital organs (*kopiopia hystericæ*), and other manifold causes of hysteric conditions. The location of an hysteric symptom is frequently more or less dependent upon an actual local lesion. Thus it is that

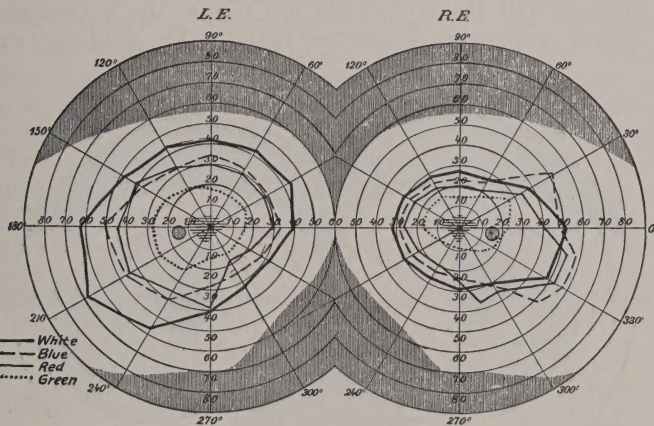


FIG. 307.—Visual fields in hysteric amblyopia, showing concentric contraction with overlapping color-fields and relative central scotomata.

the cause of hysteric blindness in a neurasthenic person may depend upon eyes that are already weak from an error of refraction or actual extrinsic muscle-weakness, conjunctival trouble, etc. There are cases in which these causes may not be found, and a diagnosis of true nervous asthenopia may here be made. There is usually weakness of accommodation and the extrinsic muscles, especially deficient adduction (insufficiency) or imbalance of the muscles (heterophoria). The levator is sometimes likewise affected (pseudoptosis). There may be sensory motor paralysis and parasthesia or anesthesia in various parts of the body.

There is generally concentric contraction of the visual field, usually

more on one side than on the other (Fig. 307). The extents and shapes of the fields will vary, depending upon the size of the test objects and the condition of the patient. The contraction may be more pronounced if a second field (the *counter-field*)¹⁵ be taken immediately after the first, the difference being caused by nervous exhaustion (*Ermüdungs-Typus*);¹⁵ or the second field may overlap the first (*Verschiebungs-Typus*)¹⁵ (Fig. 308), or the colors

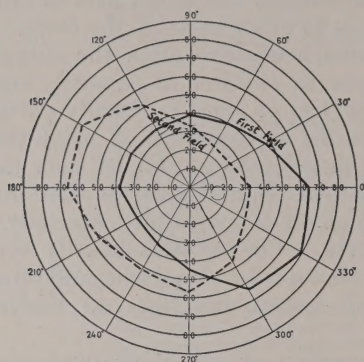


FIG. 308.—Fields for white of right eye taken fifteen minutes apart in a case of neurasthemia with diminished vision, showing overlapping of the second field, the fixation-point remaining the same (*Verschiebungs-Typus*).

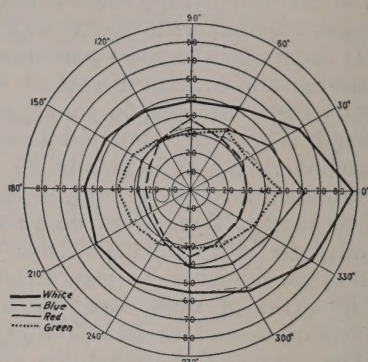


FIG. 309.—Reversal of color-fields in hysteria.

may overlap or be reversed (*reversal of the color-fields*)¹¹ (Fig. 309). Mixed forms are common and the boundaries are frequently not sharply defined. A relative central scotoma is sometimes found. The field may even have a

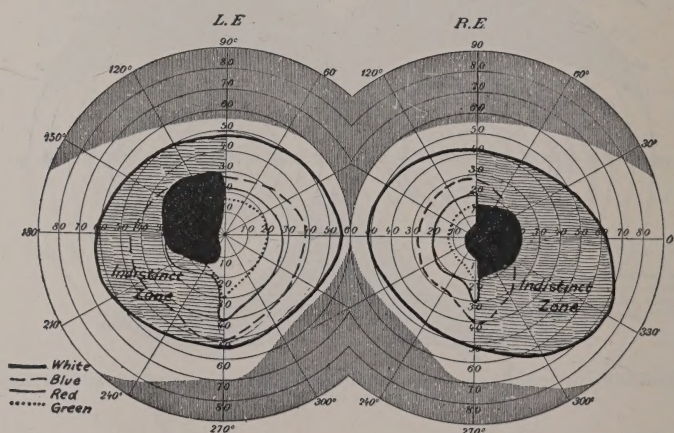


FIG. 310.—Hysteric field simulating temporal hemianopia.

hemianopic character, or be greatly contracted, or show sectoral defects (Figs. 310 and 311). A peculiar form is the oscillating field,¹⁶ in which the patient first recognizes an object at one meridian, then loses it for a moment, only to see it again.

The diagnosis may be made by the accompanying general symptoms and the absence of actual ophthalmoscopic signs of disease. The pupils are active to light and accommodation and the visual fields are usually typical. The amblyopia is usually of sudden occurrence and disappears quickly.¹¹

Treatment is directed toward restoration of general health, and should include massage, exercise, good food, and tonics, with rest of the eyes from work, and the use of tinted glasses, care being taken that the subject does not

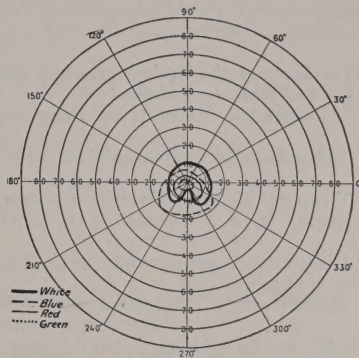


FIG. 311.—Great concentric contraction, with overlapping of the color-fields in hysteric amblyopia.

depend too much upon their use. Although subject to constant relapses, many cases may be rapidly brought from complete or partial blindness to full visual acuity and restoration of the visual field by suggestion, electrical treatment, or simple medicines.

Nerve-lesions and general diseases are sometimes attended by disturbance of vision and changes in the visual field.

The Significance of Amblyopia and Changes in the Visual Field.—The diagnostic importance of loss of vision depends upon its nature. If the disease be found in the eye, it will depend upon the extent of the lesion. If the blindness be associated with symptoms of spinal or brain disease, diagnostic points of value will be determined from study of the visual acuity, of the character and extent of scotomata, and of alterations in the field. If the latter be hemianopia in character and associated with other symptoms, a definite localization of the lesion may be assigned, although in themselves these are not diagnostic, as such may be simulated by hysteria. The character of scotomata is sometimes diagnostic, especially those of central nature which occur in toxic amblyopia. The peculiar vacillations in the visual field associated with functional disease are characteristic.

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INTRAOCULAR GROWTHS.

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OF NEW YORK CITY.

Tumors of the Iris.—Strictly speaking, tumors of the iris include cyst, sarcoma, simple granuloma, pigmented granuloma or melanoma, and angioma, although besides these primary tumors there are the nodules of tuberculosis and lepra, the condylomata and gummata of syphilis, and the lymphomata of general leukemia, which will not be treated of in this article.

I. Cysts of the Iris.—(1) *Cyst of the stroma of the iris* usually follows a perforating wound of the cornea, and appears, some months or years after the trauma, as a smooth, round tumor, translucent and non-inflammatory, projecting from the surface of the iris and distorting the pupil.

In color the cyst ranges from bluish-gray to yellow according to its size, the thickness of its walls, and the consistency of its contents.

The cyst as it grows preserves its globular form until it impinges on the cornea, when it flattens and moulds itself to the shape of the anterior chamber. At the outset it is not accompanied by signs of inflammation, but as it increases in size, particularly if the increase is rapid, there appear evidences of irritation, soon followed by true irido-cyclitis. The latter, which is associated often with glaucoma or even with sympathetic disturbance, destroys the sight and at length necessitates enucleation.

Since the growth, if neglected, is fatal to the eye, an early attempt at removal should be made, but, owing to the impracticability of extirpating the cyst entire, recurrence is usual, although cures are reported.

These cysts may be either *serous* or *epithelial*. The former are true cysts, having a wall lined with one or more layers of epithelium (or rarely endothelium), and enclosing liquid contents. When the wall is thin and the liquid clear, such a cyst may be perfectly transparent (Fig. 312).

The *epithelial cysts*, on the contrary, are composed in the periphery of stratified epithelium, which toward the center of the tumor gradually passes over into an atheromatous mass of broken-down epithelium, fat, and cholesterin. From their appearance when cut these epithelial cysts have been called *pearl tumors*, and, from their pathogenesis, *epithelial implantation tumors*.

The theory now accepted as adequate to explain the genesis of most of these tumors, and certainly of all those lined with epithelium, is that epithelial particles from the cornea, lashes, or lids are carried by the penetrating body

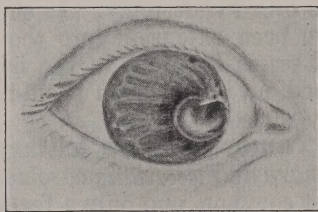


FIG. 312.—Serous cyst of the iris nine months after a perforating injury (from a patient of Dr. H. Knapp's).

into the eye, and, proliferating there, form a cyst. Cysts may readily be produced experimentally in this way.

For the rare cases in which there is no history of perforation of the cornea Schmidt-Rimpler has advanced the plausible theory that the mouth of one of the crypts in the anterior surface of the iris becomes occluded, thus forming a sac lined with the endothelium that normally covers the surface of the iris. This sac, undergoing a progressive distention with liquid, becomes a serous cyst.

(2) *Cysts of the pigment-layer of the iris* occur in eyes with broad posterior synechiæ, and are usually not discovered until the eye is cut open, although this condition has been diagnosed twice in life, the cyst presenting in the pupil as a pigmented, vibrating, translucent tumor.

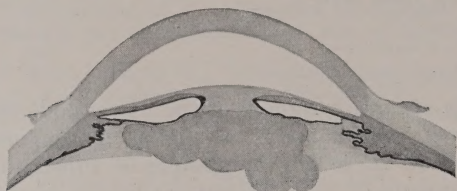


FIG. 313.—Cyst of the pigment-layer of the iris, due to membranous irido-cyclitis following a perforating injury of the cornea and lens.

These cysts are due to the drawing apart of the two strata of cells making up the posterior pigment-layer of the iris, and the filling with liquid of the cavity so produced.

Although usually small, they may involve the pigment-layer in its entire extent (Fig. 313).

Sarcoma of the Iris.—This is usually an extension of sarcoma from the ciliary body, which, passing through the head of the ciliary body, presents in the angle of the anterior chamber (Fig. 314, D).

Sarcoma may, however, be *primary* in the iris, and it then appears in middle life as a very vascular tumor, soon leading to iritis and glaucoma. It is more common in women than in men.

If *pigmented*, as it usually is, it can only be confounded with *melanoma*, which is non-vascular and non-progressive.¹ If *not pigmented*, sarcoma may be mistaken for the irregular non-vascular nodules of *tuberculosis*, which develop with a chronic iritis in young persons (see page 339).

Treatment.—In the early stages, when the growth is circumscribed, favorable results follow excision of the diseased portion of the iris by means of a broad iridectomy. It should be remembered, however, that there may have been extension into the ciliary body, even at a time when the growth still seems localized in the iris. If this point should be positively ascertained, or if extension should have taken place, thorough enucleation is the only remedy.

Tumors of the Ciliary Body.—These are *sarcoma*, *myo-sarcoma*, *primary* and *metastatic carcinoma*, *adenoma*, *nevus*, and *cyst*. Sarcoma is the most common, and only a few cases of each of the others have been reported.

Myoma and Myo-sarcoma of the Ciliary Body.—These are names given several times to tumors composed of long fusiform cells which were taken to be smooth muscle-cells springing from the ciliary muscle. The differentiation between smooth muscle-cells and the long fusiform cells of sarcoma is difficult, and it is not improbable that in some of the reported cases the tumor was an ordinary sarcoma.

Primary carcinoma and adenoma of the ciliary body may arise from the proliferation of the cells of the pars ciliaris retinæ, which is of epithelial origin. The new structure is likely to be of a glandular type. Theoretically,

¹ Benign melanoma here, as elsewhere, may in later life become sarcomatous.

similar growths could arise from the posterior pigment-layer of the iris, and such a case has been reported by Hirschberg, but he admits that the character of the growth was questionable.

Cysts may be formed in the ciliary body or choroid, or there may be detachment of the choroid with rotation inward of the ciliary body. Such conditions are readily mistaken for sarcoma of the ciliary body. Oblique illumination of the sclera in the ciliary region will show translucency in the former case, but opaqueness if a tumor is present. The tension is also of importance.

Tumors of the Choroid.—These are *sarcoma*, which is the most common; *metastatic carcinoma*, which is seen occasionally; and *cyst* and *nevus*, which are rare.

I. **Sarcoma of the Choroid and Sarcoma of the Ciliary Body.**—These growths may be described together. The course of the disease has been divided by Knapp into four stages.

Symptoms.—In the *first stage*, that of latency, the patient, who is usually past middle life, complains simply of a defect in the visual field. The media are clear, and there is seen a smooth, rounded elevation of the retina, without folds, not undulating with movement of the eye, not extending in most cases to the ora serrata, and with an overhanging margin in all or most of its extent. If the sarcoma is unpigmented, its vessels may be recognized beneath the retinal vessels. Sarcoma of the choroid usually appears of a reddish color, and sarcoma of the ciliary body black. The tension is normal and the eye is otherwise healthy.

While this condition lasts—and it may persist for years—the disease usually can be distinguished easily from spontaneous *detachment of the retina* and from *detachment of the choroid*, the two conditions that resemble it.

Spontaneous detachment of the retina is preceded by the perception of *muscæ volitantes*, and comes on suddenly. It extends to the ora serrata, and the folds into which the retina is thrown undulate with every movement of the eye. The vitreous is cloudy, signs of choroiditis are usually found in the affected eye or the other, and the tension is reduced (see page 428).

Detachment of the choroid is a very rare condition, of sudden onset, and caused, as a rule, by hemorrhage, and more rarely by exudation. Tension may be increased. The characteristic vessels of the choroid, however, can usually be recognized beneath the vessels of the retina, thus establishing the diagnosis (see page 357).

Toward the end of the first stage of the course of sarcoma the vitreous grows cloudy and a general detachment of the retina ensues, producing complete blindness. Detachment, however, is longer delayed when the tumor is in the ciliary body or near the posterior pole of the eye. The tension may still be normal for a time, and the diagnosis will then be exceedingly difficult. This is true particularly of those rare cases in which the tumor is flat, for such a growth will sometimes perforate the globe posteriorly before it presents much of a tumor in the interior of the eye. The opaque tumor can, however, sometimes be made out beneath the floating retina by using intense illumination, and its plastic features may be recognized by means of *Bellarminoff's device* of pressing a moistened plane glass upon the cornea, thus eliminating the refraction of the cornea and permitting objects in the interior of the eye to be seen more nearly in their natural size and relief. The final test of tumor is puncture. If a sarcoma is present, blood will be withdrawn, but if the condition is merely one of simple detachment of the retina, only a serous liquid will appear.

Soon after the general detachment of the retina has occurred the *second stage* of the disease is ushered in, that of *glaucoma*. The anterior ciliary veins are now dilated, more particularly on the side corresponding to the tumor, the anterior chamber is shallow, the media are cloudy, the tension is increased, and the eye is painful. There is occasionally hemorrhage into the eye, and at times the glaucomatous symptoms may mask every sign of tumor. Then the fact that the patient was blind before the glaucoma will arouse suspicion of tumor, and the coexistence of increased tension and detachment of the retina is almost pathognomonic. Cyclitis may supervene in this stage, or sarcoma may develop in an eye already shrunk from cyclitis; but these cases will be distinguished from those of uncomplicated cyclitis by the increased tension.

In the *third stage*, that of local extension, the growth spreads to parts outside of the eyeball. When the tumor is located in the anterior portion of the ball, it extends into the ciliary body, presenting in the angle of the anterior chamber, and thence passes out along the anterior ciliary vessels to form nodules in the episcleral tissue. When it is located posteriorly, the growth passes out along the *venæ vorticosæ*, or the posterior ciliary vessels and nerves, or the optic nerve, extending in the substance of the latter or between its sheaths, and then forms nodules in the orbit which cause exophthalmos.

In the *fourth stage* metastatic tumors develop in other organs, notably the liver. Even when the eye has been enucleated early, metastases occur in from 20 to 40 per cent. of the cases, and death then follows, usually within three years.

Pathological Anatomy.—The shape of the sarcomatous tumor varies with the relations of the inner layers of the choroid, which overlie it like a capsule. Rarely the tumor is diffuse and only slightly elevated, but, as a rule, it preserves a spheroidal form as long as the choroidal capsule is intact (Fig. 314, *A*). When the capsule is ruptured, however, the tumor assumes the shape of a sphere springing from a flatter base (Fig. 314, *B*), and later the entire mass may again become spheroidal (Fig. 314, *C*).

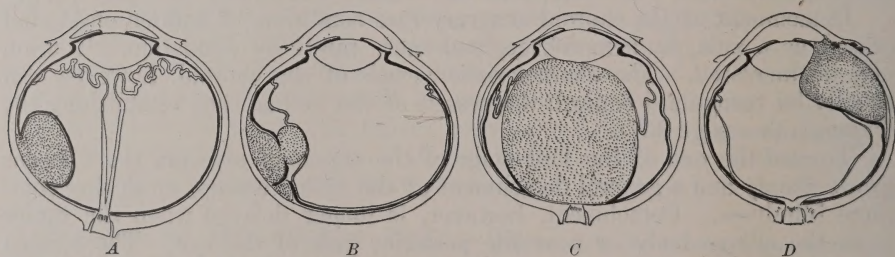


FIG. 314.—Diagrams of sarcoma of the uveal tract, the heavy line representing the tumor-capsule.

A second nodule developing near the first may remain permanently separated from the other by its capsule (Fig. 314, *B*). When the tumor is in the ciliary body, the anterior portion breaks through the capsule early and impinges on the lens, dislocating and distorting it (Fig. 314, *D*). The retina, which in the normal state is but loosely attached to the choroid, may readily undergo a total funnel-shaped detachment while the capsule is still intact (Fig. 314, *A*). But when the growth perforates the capsule the retina becomes adherent at the point of perforation, and remains attached there, although it may otherwise be detached entirely (Fig. 314, *B* and *C*).

The consistency of sarcoma is generally firm, although the tumor may be

PLATE 8.

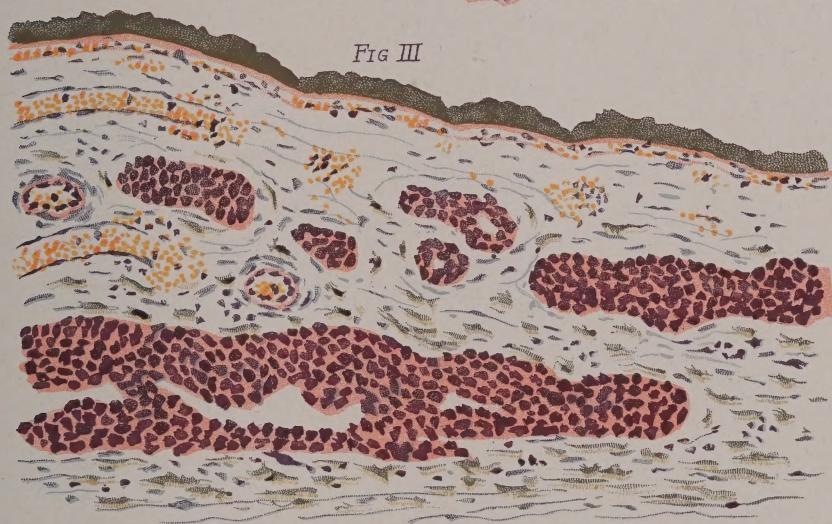
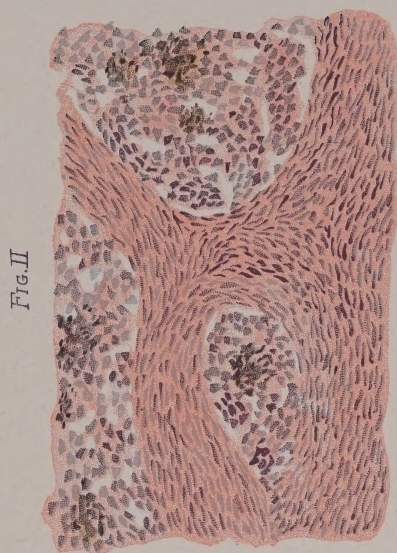
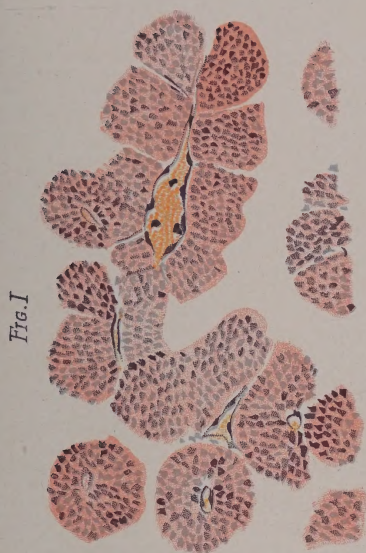


FIG. I.—Vascular round-celled sarcoma of choroid.
 FIG. II.—Non-vascular spindle-celled sarcoma of choroid.
 FIG. III.—Metastatic carcinoma of choroid.

gelatinous, and it may undergo fatty, myxomatous, cartilaginous, or osseous degeneration.

The pigmented variety (*melano-sarcoma*) is much more frequent than the unpigmented (*leuko-sarcoma*). The pigment of melano-sarcoma may lie only in a few cells along the vessels, or may color single tracts of cells, or every cell in the tumor may be black with pigment. The pigmentation is usually denser in the periphery of the tumor than in the center.

Sarcoma of the uveal tract may occur in many of the protean forms in which sarcoma is found elsewhere, and more than one type of structure may be represented in the same tumor. The cells are usually small, and the spindle-cell is commoner than the round. There are all degrees of vascularity, from the type in which the tumor is made up of thin-walled vessels, each surrounded by a sheath of epithelioid cells arranged in concentric layers (Plate 8, Fig. I.) to the type in which tracts of spindle-cells run in various directions, and often in a considerable field the only trace of a vessel to be seen is a spot of pigment in the center of a tract cut transversely, representing the remains of a previously-existing vessel about which the tract developed (Plate 8, Fig. II.). Alveolar forms of sarcoma are also found occasionally, and these in former days were sometimes described as carcinoma.

Prognosis.—If an eye with sarcoma of the uveal tract is enucleated before there are visible evidences of extension, the chances of local return are slight; the prognosis as regards metastasis, however, is grave. If we take the average of the statistical tables that have been published, it appears that there is eventually a fatal result in about 30 per cent. of cases.

Treatment.—The treatment is prompt enucleation as soon as the diagnosis of sarcoma is made. The optic nerve is to be resected far back, and evidences of extension are to be looked for, since the presence of nodules outside of the eyeball usually calls for evisceration of the orbit.

II. Metastatic Carcinoma of the Choroid.—This growth has been seen a score of times at the posterior pole of the eye as a broad, flat patch of dull yellow mottled with white and some spots of pigment, with fine vessels running through it, elevated some millimeters in its central portion, and at its periphery passing over into the healthy choroid without a sharp line of demarcation. Not infrequently more than one patch is present, and the patches then tend to coalesce and surround the optic disk.

At first glance carcinoma might be mistaken for an exudation in the choroid, but the details of the growth are too clearly defined for this, and there are wanting the congestion and edema of the disk and retina that would accompany an inflammatory exudation. Carcinoma has a slow progressive course, first elevating the retina and producing hyperopia, then interfering with its function and causing a scotoma. Later, the retina is detached. In nearly every case the primary carcinoma has been located in the breast, and in a number of cases both eyes have been affected.¹

The epithelial cells from the primary growth are carried into the eye through the posterior ciliary arteries, and, lodging in the chorio-capillaris, they proliferate and invade all the layers of the choroid (Plate 8, Fig. III.).

As with metastatic tumors elsewhere, nothing can be gained by operative interference, although in the glaucomatous stage enucleation has been done for the relief of pain.

Flat tumors of the choroid have proved in a few instances to have the character of *angioma* or *cavernoma*, and the designation *nevus* seems fitting.

¹ It may be noted here that in the rare cases in which sarcoma of the choroid is metastatic the tumor is likely to assume this same flat form.

Tumors of the Retina.—These are *cyst* and *glioma*.

I. **Cysts** are found occasionally in the detached retinas of degenerated eyes, but since the media in such eyes are cloudy, the cysts are rarely discovered until after enucleation. It may happen, however, if the cysts lie far forward and the lens is not entirely opaque, that they may be indistinctly seen in life, as they were in the eye represented in Fig. 315; and the cysts might then be mistaken for tumors of the ciliary body did not the reduced tension and the clinical history oppose that diagnosis.

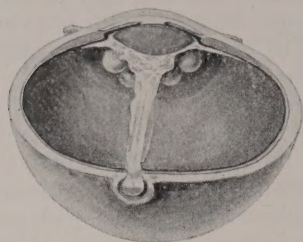


FIG. 315.—Multiple cysts of the detached retina in an eye with plastic cyclitis from a non-perforating injury.

These cysts are due to disturbances of circulation whereby a liquid transuded from the retinal vessels collects in little cysts, until at length the retina, for some distance, is split into two layers.

II. **Glioma of the Retina.**—This is the most malignant tumor of the eye, and is sometimes present at birth, but usually appears within the first two years of life and never later than the eleventh year. In one-fifth of the cases the disease affects both eyes.

Symptoms.—The clinical course of glioma may be divided into four stages, like that of sarcoma :

In the *first stage* the attention of the parents is attracted by a dilated pupil and a whitish reflex from the interior of the eye. If the glioma has grown from the posterior surface of the retina backward (*glioma exophytum*), the commoner form, it will push the retina forward, so that the latter will be seen, with its characteristic vessels, forming the nodular and uneven surface of the tumor. Portions of the retina not involved in the growth may be detached and undulating. The color of the tumor is bright pale yellow or pink, with scattered spots of white. If the glioma has grown from the anterior surface of the retina forward (*glioma endophytum*), a much rarer form, there will be seen a number of light-colored nodules projecting forward into the vitreous in front of the retina, which is thickened and uneven.

When the growth has reached a considerable size the *glaucomatous stage* comes on, with injection of the eyeball, shallow anterior chamber, cloudiness of the media, and increased tension. In this stage cyclitis may supervene, causing a temporary shrinking of the ball and masking the presence of the growth—a condition known as *crypto-glioma*.

In the *third stage* there is extension, usually first along the optic nerve, and then through the cornea, which is destroyed. The orbit thus becomes filled with a fungoid mass, and at the same time the tumor attacks the glands of the head, and scattered nodules form on the bones of the skull.

Finally, in the *fourth stage*, metastases develop in other organs.

Diagnosis.—This is often exceedingly difficult, but, owing to the malignancy of the growth, enucleation is usually done when there is a reasonable assurance that the disease is glioma; consequently, many of the eyes enucleated with this diagnosis are found on examination not to contain a glioma, but to represent one of the several conditions called pseudo-glioma.

Pseudo-glioma may consist in a malformation of the anterior portion of the vitreous, with persistence of the embryonic hyaloid artery and vascular sheath of the lens—a condition whose nature can usually be recognized. It may be solitary tubercle, and then, as in glioma, enucleation is indicated if the tuberculosis is limited to the eye and sight has been destroyed. But in

the great majority of cases pseudo-glioma is an exudation into the vitreous chamber following meningitis.

An infant has fever with meningeal symptoms, and shortly afterward a whitish reflex is noticed from the pupil. The iris is normal or only atrophied in spots, but its ciliary margin is retracted by cyclitic membranes, so that the periphery of the anterior chamber is very deep, while the pupillary margin of the iris is pushed forward by the lens, rendering the center of the anterior chamber shallow. The pupil is usually small, and the iris, as a whole, has the peculiar appearance of a truncated cone, which is characteristic of membranous cyclitis.

In the vitreous chamber a smooth exudation will be found, dull yellow or gray in color, and without visible blood-vessels. The tension is generally reduced. Later small vessels may appear in the exudation, the retina may become detached, and the eyeball may even shrink. This condition is brought about by a metastatic uveitis or retinitis due, as a rule, to meningitis, but also coming on in pyemia and various other infectious diseases. Syphilis and penetrating wounds may also give rise to a similar exudation.

Glioma, however, is distinguished from these conditions by the normal or increased tension, the dilated pupil, the normal or uniformly shallow anterior chamber, and by the nodular surface of the growth with its characteristic retinal vessels (see also pages 356 and 400).

Pathological Anatomy.—Glioma of the retina is a soft vascular tumor, composed of small cells with a large nucleus, imbedded in a delicate mesh-work of cell-processes and fibers. It readily undergoes fatty and even calcareous degeneration. In the hardened specimen thick sheaths of healthy cells are seen surrounding the thick-walled and often degenerated blood-vessels, while the cells farther from the nutritive supply are degenerated and do not take the nuclear stains.

Virchow first thought glioma to be a proliferation of neuroglia tissue; others have put it in the category of sarcoma; and there has been much discussion as to what layer of the retina glioma really springs from, and what is its true nature, some contending that a simple proliferation of neuroglia tissue could not have the extreme malignancy of glioma, which spares no tissue in the body.

Sections of glioma stained by the Golgi-Cajal silver-impregnation method have recently shown us that glioma is composed of neuroglia-tissue and a few nerve-cells of various sizes (Fig. 317). Glioma in rare instances contains tubules composed of a thin elastic membrane surrounded by long cylindrical cells, each sending a process through the membrane into the lumen of the tubule. The elements of these tubules are histologically analogous to the cone-nucleus, membrana limitans externa, and cone-body of the normal retina, and such tumors have been called *neuro-epithelioma*.

The **prognosis** of glioma is very bad, only about 10 per cent. of the patients being permanently cured by operation, the others dying mostly within a year, from local recurrence.

Treatment.—Enucleation should be done early and the optic nerve resected far back. If the disease has extended into the orbital tissues behind the eyeball, only complete evisceration of the orbit with removal of the periosteum can be of any avail.

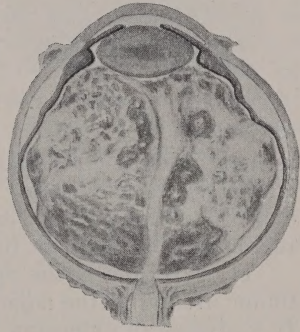


FIG. 316.—Glioma exophytum.

Tumors of the Intraocular End of the Optic Nerve.—These include *hyaline bodies* and *sarcoma*.

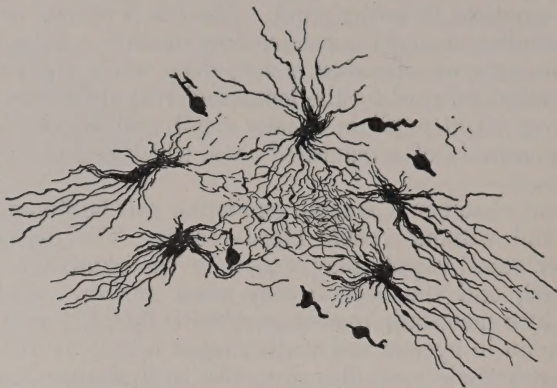


FIG. 317.—Glioma stained by Golgi's method, showing neuroglia-tissue and scattered small nerve-cells.

I. **Hyaline bodies** are found in the optic disks of young persons with eyes otherwise healthy and having normal vision, and also in eyes with optic neuritis or with pigmentary or albuminuric retinitis. In most cases a few discrete, lustrous, pearly globules are seen in the disk, but these globules may be present in such number as to cover the disk, and even spread beyond it in a confluent mass like frog-spawn (see Fig. 265).

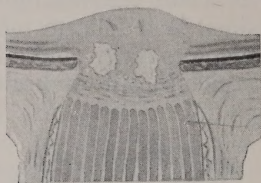


FIG. 318.—Hyaline bodies in the nerve-head.

Microscopically, we find laminated hyaline masses lying among the fiber-bundles. The exact pathogenesis of these bodies is unknown, the old view, that they are products of the retinal pigment-epithelium, like the so-called colloid excrescences on the lamina vitrea, now being given up, since the bodies are often present in the disk when the pigment-epithelium is healthy (Fig. 318), and they are never surrounded by pigment like the others (see also page 453).

II. **Sarcoma of the optic disk** has been seen a few times as a hemispherical tumor involving the adjacent retina and projecting forward into the vitreous. It is always an extension from sarcoma farther back in the optic nerve, and it can be differentiated from a tumor of the choroid overlapping or involving the disk by the fact that the retrobulbar tumor from which it extended must have caused an exophthalmos before the tumor appeared in the eye.

MOVEMENTS OF THE EYEBALLS, AND THEIR ANOMALIES.

BY ALEXANDER DUANE, M. D.,
OF NEW YORK CITY.

Physiological Action of the Ocular Muscles.¹—The actions of the external ocular muscles, deduced partly from our knowledge of their origins and insertions, partly from the results produced by their paralysis, are as follows:²

The external rectus (abducens) rotates the eye directly outward (*abduction*).

The internal rectus rotates the eye directly inward (*adduction*).

The superior rectus carries the eye upward, adducts it, and rotates the upper end of the *vertical meridian* of the cornea inward (*inward torsion, intorsion*). Its power of producing adduction and torsion increases as the eye is adducted, and decreases as the eye is abducted; its elevating power, on the contrary, is greatest when the eye is abducted between 20° and 30° , and diminishes to zero as the eye is adducted.

The inferior rectus carries the eye downward, adducts it, and causes outward torsion of the vertical meridian of the cornea (*extorsion*). As in the case of the superior rectus, the power of producing adduction and torsion increases and the vertical action diminishes the more the eye is carried inward; and, contrariwise, it acts most powerfully as a depressor (and not at all as an adductor) when the eye is abducted 20° or 30° .

The superior oblique (trochlearis) depresses the eye, abducts it, and rotates the vertical meridian inward. The power of producing abduction and torsion increases and the vertical action decreases in proportion as the eye is abducted. In positions of adduction, on the contrary, the superior oblique serves mainly to depress the eye, its action in this regard increasing as that of the inferior rectus diminishes.

The inferior oblique elevates the eye, abducts it, and rotates the vertical meridian inward. The power of producing abduction and torsion increases in proportion as the eye is abducted, while the elevating action increases as the eye is adducted, the effect of the muscle in this regard becoming constantly greater as that of the superior rectus grows less.

It will be seen from this that elevation and depression of the eye are effected mainly by the obliques when the eye is adducted and by the superior and inferior recti when the eye is abducted; also that the adducting action of

¹ See also pages 41, 42, and 100.

² The researches of Volkmann and Fuchs upon the insertion of the ocular muscles have shown that slight variations from the actions here laid down may occur; but such variations are inconstant, and in no case great enough to invalidate the statements of the text.

the superior and inferior recti increases (and the opposing action of the obliques diminishes) in proportion as the eye is adducted; and that the abducting action of the obliques increases (and the opposing action of the recti diminishes) in proportion as the eye is abducted. Hence, while abduction is performed mainly by the external rectus, the latter is reinforced especially toward the end of its course by the obliques; and the internal rectus is similarly reinforced by the superior and inferior recti, which, when the eye is already much adducted, will carry it appreciably farther in.

Lastly, it will be seen that, in directions of the gaze up and in, the torsion-action of the superior rectus will predominate; in directions up and out, that of the inferior oblique; in directions down and out, that of the superior oblique; and in directions down and in, that of the inferior rectus. Consequently, when we look up and in or down and out, the vertical meridian of the cornea is tilted toward the nose; when we look up and out or down and in, it is tilted toward the temple. When we look straight up or straight down (and also when we look straight to the right or left), the torsion actions of the oblique muscles and of the recti counteract each other, and hence the vertical meridian remains vertical.

Movements of Each Eye.—By the combined action of two or more ocular muscles the eye may be moved in any direction whatever. Thus a movement obliquely upward and inward requires the co-operation of three muscles—*i. e.* of both elevators and of the internal rectus, the latter (assisted by the superior rectus) carrying the eye inward, while the inferior oblique and, to a moderate extent, the superior rectus carry it upward.

In moving the eye obliquely up or down three muscles are always called into play (*viz.* both elevators or both depressors, combined with either the external or the internal rectus); in moving the eye straight upward, four (*i. e.* all except the two depressors); in moving the eye straight downward, four (all except the two elevators); in moving the eye directly inward, five (all except the external rectus); and in moving it directly outward, five (all except the internal rectus).

All these movements start from a position of rest, or *primary position*. When the eye is in this position the muscles are all balanced—*i. e.* if all six contract simultaneously to an equal extent, they will keep the eye fixed where it is. In all other directions of the gaze (*secondary positions*) the eye is so placed that some one muscle or pair of muscles works to greater advantage than the antagonistic muscle or pair. In this case, if all six muscles contract simultaneously, the muscle that works to greater advantage will exert a preponderating action, and will hence tend to displace the eyeball away from the position it occupies, and in such a manner always as to carry it back toward the primary position.

For most eyes the primary position is that in which the visual line is directed horizontally or nearly so and straight ahead (*i. e.* is perpendicular to the line joining the centers of rotation of the two eyes).¹ The eyes should always be placed in this position when any tests are made for ascertaining whether or not the muscles are in equilibrium.

Field of Fixation.—By passing from the primary to all possible secondary positions the eye is enabled to fix a great number of objects—*i. e.*

¹ The primary position is more exactly defined as being the only position from which both vertical and horizontal movements can be executed without affecting the position of the vertical meridian of the cornea. Movements from one secondary position to any other in general cause a rotation of the vertical meridian (torsion movement), which can be demonstrated by means of the after-images. This fact is utilized in determining experimentally when the primary position has been reached.

bring the images of these objects successively upon the macula. The portion of space occupied by all such objects that can thus be fixed by movement of the eye alone without moving the head is called the *field of fixation*.

Its limits represent the limits of excursion of the eye in all possible directions. These limits can be best determined by fixing the patient's head upon the rest of a perimeter in such a way that the eye when in the primary position is directed toward the zero of the perimetric arc, and then carrying along the latter a card with two fine dots set close together upon it. The patient is told to follow the dots with his eye without moving his head. The moment when he fails to do so is evidenced objectively by the wavering of the eye, and subjectively by the fact that the two dots are no longer seen distinctly as two, but run into one. Then the point on the perimetric arc to which the card has been carried indicates the amount of excursion of the eye in the given direction.

The limits of the field of fixation have been variously stated. My own observations (37 measurements of 18 different subjects) gave—

Field of Fixation.

	Up.	Up and out.	Up and in.	Out.	In.	Down.	Down and in.	Down and out.
Average	43°	46°	49°	51°	53°	63°	54°	61°
Minimum	35°	35°	35°	40°	40°	35°	32°	38°

Reduction of the excursion of the eye (*contraction of the field of fixation*) to less than 30° in any direction must, if substantiated by repeated tests, be regarded as distinctly pathological (see also page 169).

Binocular Vision and Diplopia.—We ordinarily use both eyes in seeing (*binocular vision*), and the eyes are involuntarily so adjusted that the image of the object looked at falls simultaneously upon both maculæ (*binocular fixation*). Under these conditions we see singly because the two images are by our consciousness fused into one image, which has somewhat different characters from either of its components (*binocular single vision*). When one eye fails to fix simultaneously with the other, diplopia generally results. But diplopia will be absent if, as often happens, the image formed in the non-fixing eye is not taken account of by the consciousness (*monocular vision from suppression of image*); and one image may be thus suppressed even when both eyes are properly directed—*i. e.* there may be binocular fixation, but only monocular vision.

The *diplopia* produced by the fact that one of the eyes deviates from the object that the other eye is looking at is directly proportional to the amount of deviation. It may be *corrected* by an appropriate movement of the deviating eye or by placing before the eye a prism so directed as to make the rays coming from the object change their course and fall upon the macula.

Per contra, *diplopia may be produced without any deviation of the eyes* by putting before the latter a prism which will deflect off from the macula the rays that would otherwise be concentrated upon it. In this case the artificial diplopia may be corrected (or the *prism may be "overcome"*) by turning the eye until the macula is so directed as to meet the deflected rays.

When an eye either is deflected to the right or has placed before it a prism with its base directed to the right, an object situated straight ahead will form its image to the right of the macula, instead of upon the latter. But experience and the sense of touch continually teach us that an object which forms its image on the right of the macula is itself situated to our left;

hence, under the conditions noted the object no longer appears straight ahead, but deflected to the left, and by as great an amount as the eye itself is deflected to the right. So also when the eye is deviated up, an object straight ahead appears lower than it is; and in general, however an eye may be deflected, the apparent position of objects seen with it is deflected in the contrary way.

These facts may be expanded for the particular cases as follows :

Varieties of Diplopia.

NAME.	CHARACTER: Image of R. eye as compared with that of L. is	CAUSED BY		CORRECTED BY	
		(1) A natural deviation of	(2) Artificially by a prism placed, base	(1) Turning	(2) Prism placed, base
Homonymous diplopia.	On R. side.	Either eye <i>inward</i> (esophoria, strabismus convergens).	<i>In</i> , before either eye.	Both eyes <i>outward</i> . (Divergence.)	<i>Out</i> before either eye.
Heteronymous (crossed) diplopia.	On L. side.	Either eye <i>outward</i> (exophoria, strabismus divergens).	<i>Out</i> , before either eye.	Both eyes <i>inward</i> . (Convergence.)	<i>In</i> before either eye.
Right diplopia.	Below.	R. eye <i>up</i> or L. eye <i>down</i> (R. hyperphoria).	<i>Up</i> before R. eye or <i>down</i> before L. eye.	R. eye <i>down</i> , and L. eye <i>up</i> . (L. sursumvergence.)	<i>Down</i> before R. eye or <i>up</i> before L. eye.
Left diplopia.	Above.	R. eye <i>down</i> or L. eye <i>up</i> (L. hyperphoria).	<i>Down</i> before R. eye or <i>up</i> before L. eye.	R. eye <i>up</i> , and L. eye <i>down</i> . (R. sursumvergence.)	<i>Up</i> before R. eye or <i>down</i> before L. eye.
Homonymous torsion-diplopia.	Tilted to R.	Either vertical meridian <i>inward</i> (convergence of meridians).	...	Both vertical meridians <i>outward</i> . (Distorsion.)	
Heteronymous torsion-diplopia.	Tilted to L.	Either vertical meridian <i>outward</i> (divergence of meridians).	...	Both vertical meridians <i>inward</i> . (Contorsion.)	

Associated Movements of the Two Eyes: Parallel Movements.

—As has been stated, binocular single vision is attained only when both eyes are directed precisely at the object of fixation, and under normal conditions the two eyes invariably move together in such a way as to effect this end, and that, too, at once and with the utmost precision. In the case of a distant object the movements of the eyes must be such as to keep the two visual lines strictly parallel (*associated parallel movements*). The typical movements of this class are shown in the following table :

Associated Parallel Movements.

(a) Both eyes move directly to R. (Dextroversion).

R. eye carried to R. by external rectus, assisted, especially toward the end of its excursion, by the two obliques. The latter, together with the superior and inferior recti, by their equal counter-traction steady the eye, and thus both maintain it in the horizontal plane and keep its vertical meridian vertical.

L. eye carried to R. by internal rectus, assisted, especially toward the end of its course, by the superior and inferior recti. The latter, together with the obliques, by their equal counter-traction steady the eye and keep its vertical meridian vertical.

(b) Both eyes move directly to L. (Lævoersion).

R. eye carried to L. by internal rectus, assisted, especially toward the end of its excursion, by the superior and inferior recti. The latter, together with the obliques, by their equal counter-traction steady the eye and keep its vertical meridian vertical.

L. eye carried to L. by external rectus, assisted, especially toward the end of its course, by the obliques. The latter, together with the superior and inferior recti, by their equal counter-traction steady the eye and keep its vertical meridian vertical.

(c) *Both eyes move directly up (Sursumversion).*

R. eye carried up by superior rectus and inferior oblique. These muscles exactly neutralize each other in their lateral tendencies and their action upon the vertical meridian, so that the eye goes straight up and the vertical meridian remains vertical. The external and internal recti steady the eye.

L. eye carried up by superior rectus and inferior oblique, and steadied by external and internal recti, as in the case of the R. eye. Vertical meridian remains vertical.

(d) *Both eyes move obliquely up and to R.*

R. eye carried up mainly by superior rectus; to R. mainly by external rectus, assisted by inferior oblique. The torsion action of the latter preponderating over that of the superior rectus, the vertical meridian is rotated out (to the R.).

L. eye carried up mainly by inferior oblique; to R. by internal rectus, assisted by superior rectus. The torsion action of the latter preponderating over that of the inferior oblique, the vertical meridian is rotated in (to the R.).

(e) *Both eyes move obliquely up and to L.*

R. eye carried up mainly by inferior oblique; to L. by internal rectus, assisted by superior rectus. The torsion action of the latter preponderating over that of the inferior oblique, the vertical meridian is rotated in (to the L.).

L. eye carried up mainly by superior rectus; to L. by external rectus, assisted by inferior oblique. The torsion action of the latter preponderating over that of the superior rectus, the vertical meridian is rotated out (to the L.).

(f) *Both eyes move directly down (Deorsumversion).*

R. eye carried down by inferior rectus and superior oblique. These muscles exactly neutralize each other in their lateral tendencies and their action upon the vertical meridian, so that the eye goes straight down and the vertical meridian remains vertical. The external and internal recti steady the eye.

L. eye carried down by inferior rectus and superior oblique and steadied by the external and internal recti, as in the case of the R. eye. Vertical meridian remains vertical.

(g) *Both eyes move obliquely down and to R.*

R. eye carried down mainly by inferior rectus; to R. by external rectus, assisted by superior oblique. The torsion action of the latter preponderating, the vertical meridian is rotated in (to the L.).

L. eye carried down mainly by superior oblique; to R. by internal rectus, assisted by inferior rectus. The torsion action of the latter preponderating, the vertical meridian is rotated out (to the L.).

(h) *Both eyes move obliquely down and to L.*

R. eye carried down mainly by superior oblique; to L. by internal rectus, assisted by inferior rectus. The torsion action of the latter predominating, the vertical meridian is rotated out (to the R.).

L. eye carried down mainly by inferior rectus; to L. by external rectus, assisted by superior oblique. The torsion action of the latter predominating, the vertical meridian is rotated in (to the R.).

An inspection of the foregoing table will show that the twelve muscles that serve to carry the two eyes in parallel directions may be divided into six pairs, one muscle of each pair being in the right eye and the other in the left, and the two moving their respective eyes in the same direction and to the same extent. The muscles constituting such a pair are called *associated antagonists*.

Associated Antagonists.

R. eye.	L. eye.	Moves eye to which it belongs—
External rectus.	Internal rectus.	To R. (dextroduction). No vertical nor torsion action.
Internal rectus.	External rectus.	To L. (lævoduction). No vertical nor torsion action.
Superior rectus.	Inferior oblique.	Up, to L. (lævoduction), and rotates vertical meridian to L. (lævotorsion). Elevating action increases as eyes are carried to R.; lateral and torsion movements increase as eyes are carried to L.
Inferior oblique.	Superior rectus.	Up, to R. (dextroduction), and rotates vertical meridian to R. (dextrotorsion). Elevating action increases as eyes are carried to L.; lateral and torsion actions increase as eyes are carried to R.
Inferior rectus.	Superior oblique.	Down, to L. (lævoduction), and rotates vertical meridian to R. (dextrotorsion). Depressing action increases as eyes are carried to R.; lateral and torsion actions increase as eyes are carried to L.
Superior oblique.	Inferior rectus.	Down, to R. (dextroduction), and rotates vertical meridian to L. (lævotorsion). Depressing action increases as eyes are carried to L.; lateral and torsion actions increase as eyes are carried to R.

The amount of excursion in every direction made by a pair of eyes in following a more or less distant object which they simultaneously fix determines the *field of binocular fixation*; and the amount of excursion that they can make and yet preserve parallelism of their axes, so that no diplopia ensues, determines the *field of binocular single vision*. This latter extends not less than 40° (normally from 40° to 50°) in every direction from the primary position; and diplopia, occurring uniformly when the eyes have been carried less than 30° from the primary position, is distinctly pathological.

The tendency to maintain parallelism of the visual lines is so great as to persist even when one eye is excluded by blindness or by being covered with a screen; so that one eye keeps moving with the other, and binocular fixation is maintained in all directions of the gaze, although only one eye sees the object fixed. Upon this fact depends the test by alternate covering (*screen test*).

The associated parallel movements are apparently governed by a *nervous mechanism* distinct from the nuclei that supply the nerves for the ocular muscles; and each of the typical movements (*dextroversion*, *sinistroversion*, *sursumversion*, *deorsumversion*, and perhaps the *oblique movements* also) seems to have its separate center. The precise location of these centers, however, has not yet been satisfactorily determined.

Movements of Convergence.—By means of the associated parallel movements both eyes can be simultaneously directed at any distant object situated within the limits of the field of fixation. To direct them both at once at some near object requires a greater or less degree of *convergence* of the visual lines, and this is effected by a simultaneous equal contraction of the two interni. This movement, which under normal conditions takes place invariably, immediately, and with the utmost precision, and which, as in the case of the associated parallel movements, takes place even when one eye is excluded from seeing, is apparently governed by a *nerve-center* distinct from the nerve-nuclei of the internal recti.

When the object looked at is situated not straight ahead, but to one side or above or below, binocular fixation is effected by a combination of convergence with an associated parallel movement. Thus, in looking at an object situated near the eyes and 45° to the right of the median line, the two eyes first move, each, 45° to the right by a simultaneous equal contraction of the

right externus and the left internus (*dextroversion*); then by a simultaneous equal contraction of the right internus and the left internus (*convergence*) the right eye is turned somewhat to the left again and the left eye somewhat farther on to the right, until both visual lines are properly directed.

Even without being adjusted for near objects, the eyes tend to converge somewhat when directed downward.

The amount of convergence is measured by the distance from the nose of the point (*convergence near-point*, *Pc*) upon which the eyes can by the utmost effort be made to converge. This should be from 1 to $1\frac{3}{4}$ inches from the nose. The convergence is also measured by the degree of prism, placed base out before the eyes, which the latter can overcome by turning inward (*prism-convergence*, improperly called the *adduction*). The prism-convergence, when a distant test-object is used, is represented by prisms of 60° to 90° total refracting angle (= a convergence of the visual lines of 35° to 60°).

The maximum amount that each eye turns inward in performing convergence (*convergence-adduction*) is about 30° – 35° . It is somewhat less, therefore, than the amount (40° – 50°) by which each eye can turn inward when moving parallel with its fellow (*associated adduction* or *adduction proper*).

Movements of Divergence.—In passing from the consideration of near objects to those more remote the eyes diverge from each other. They can even diverge beyond parallelism (*i. e.* become absolutely divergent), as, for example, when they look at a distant object through a prism placed, base in, before them, and then overcome the diplopia which the latter produces. The amount of this absolute divergence or diverging power (*prism-divergence*, improperly called the *abduction*) is from 6° to 8° prism (= an actual separation of the visual lines of only 3° to 4°). The absolute diverging power (*divergence-abduction*) of each eye, therefore, amounts to only 2° . It must not be confounded with the *abduction proper* (*associated abduction*), or absolute degree of rotation of each eye outward in performing associated parallel movements, which is 40° – 50° .

The movement of divergence consists either in a simultaneous equal relaxation of the two interni, or, more probably, in a simultaneous equal contraction of the two externi. It is often combined with associated parallel movements. Thus, if a prism of 8° is placed, base in, before the left eye, each eye will turn out through an angle of 2° in order to fuse the double images (*divergence*); then, in order to bring the images on the maculæ of the two eyes, each eye will turn 2° to the left (*sinistroversion*), so that the right eye is directed straight ahead, the left eye 4° to the left.

A slight divergence of the visual lines occurs normally when both eyes are directed upward.

Movements of Sursumvergence.—Divergence of the visual lines in a vertical plane, so that one rises above the other, is called *sursumvergence*,¹ and this, again, is denoted as *right* or *left* according as the right or left eye is the higher. Right and left sursumvergence are normally equal, but are very limited in amount (= only 2° prism, or 1° of actual separation of the visual lines). The movement is undoubtedly distributed equally between the two eyes, so that a movement of right sursumvergence is the same thing as a movement of left deorsumvergence—*i. e.* in both cases the right visual line moves up and the left visual line moves down, and each moves to an equal extent. Neither the upward movement of one visual line nor the downward movement of the other can be regarded as a measure of the power of the

¹ Usually called sursumduction, but this term is properly applied to mean the absolute degree of movement of either eye upward—a movement of some 40° in extent.

elevators and depressors of the eye, which is determined rather by the sursumduction (in the proper sense of the term)—*i. e.* the absolute ability of either eye to move upward (= about 40°), and the deorsumduction, or ability of either eye to move downward (= 50° – 60°).

Right sursumvergence is measured by the degree of prism placed base down before the right eye (or base up before the left eye), and *left sursumvergence* by the prism placed base down before the left eye (or base up before the right eye), which the eyes can overcome.

VARIETIES, CLASSIFICATION, ETIOLOGY, AND GENERAL SYMPTOMS OF MUSCULAR ANOMALIES.

Varieties of Deviations.—All the movements of the eyes, described above, may be deranged pathologically, and the derangement may take the form of over-action, under-action, or perverted action. The result of these derangements is that binocular fixation and binocular single vision are interfered with, so that one of the eyes deviates or tends to deviate from the object looked at.

Strabismus and Heterophoria.—A marked deviation which the patient cannot in general overcome is called a *squint* or *strabismus* (heterotropia, manifest deviation); one which, being moderate in amount, is habitually overcome by muscular effort, and hence is elicited only by special tests, is called a *heterophoria* or *insufficiency* (latent squint, latent deviation).

A deviation is further classed as *constant*, if present all the time; *intermittent*, if sometimes present, sometimes absent; and *periodic*, if regularly recurring under certain conditions (*e. g.* if the accommodation is used).

Measurement of Deviations.—The magnitude of the deviation may be measured directly by ascertaining either how far the deviating eye stands in or out when the other eye is looking straight ahead, or how far it has to turn in or out in order to perform fixation when the other eye is screened (*screen-test*). The amount of this deflection or of this movement may be got at by taking a linear measurement along the edge of the lower lid,¹ or it may be determined directly in degrees by means of a perimeter or a tangent scale. Objective measurement performed in this way is termed *strabometry*.

Indirectly, the amount of a deviation is determined by the amount of diplopia which it produces, this latter, again, being measured either by the actual distance between the double images or by the strength of the prism required in order to unite them (see *Table of Diplopia*, p. 500). When no diplopia exists spontaneously, the artificial diplopia produced by the various forms of *phorometer* and the amount of *parallactic displacement* that the object looked at undergoes when a screen is shifted from one eye to the other, serve as a precise measure of the deviation.

It frequently happens, especially in constant and periodic squint, that the deviation is confined to one eye, the other performing fixation all the time. In this case the non-fixing eye is apt to be amblyopic; but whether the poor sight is congenital and gives rise to the deviation, or whether it is itself the result of the latter and springs from the habitual suppression of the visual image (amblyopia from disuse, *amblyopia exanopsia*) or from the injurious effects of the diplopia upon the squinting eye, is not certain.

In many cases, especially in intermittent squint, and almost always in

¹ Each millimeter = about $4\frac{1}{2}^\circ$ actual deviation.

heterophoria, fixation is performed by each eye alternately (*alternating deviation*).

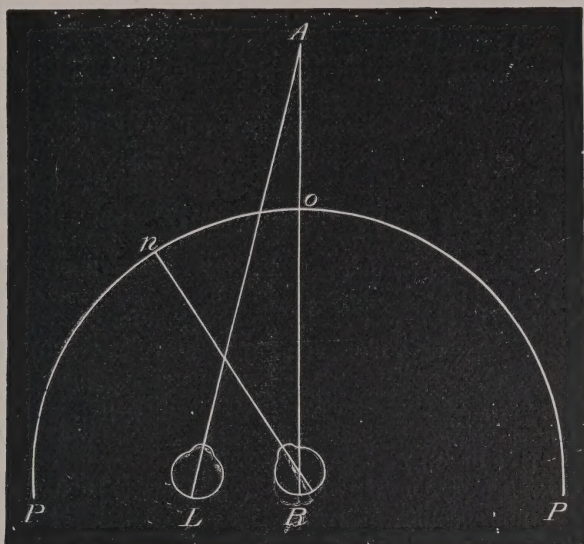


FIG. 319.—Measurement of squint with a perimeter:

The deviating eye *R* is placed at the center of the graduated arc of the perimeter *PP*, the arc lying on the plane of the deviation. The patient is then required to fix with his two eyes a distant object, *A*, situated along the central radius *RoA*. This is the direction which the deviating eye should have in the normal condition. The point *n* to which the eye in reality is directed should now be determined; the angle *ORn*, formed by the deviating line of sight *n* with the normal line of sight *AoR*, is the *angle of the strabismus*. In order to obtain this angle, it would be necessary only to determine the precise direction of the line of sight of the deviating eye. As this is not an easy matter, it is sufficient in practice to determine the direction of the corneal axis; this differs from the former only by a small angle, which, in comparison with the large angle of the strabismus, may be neglected. The flame of a candle is moved along the arc of the perimeter until its reflection is in the center of the pupil. This will occur when the flame is at *n*. The corneal axis has now been found, and the size of the angle of strabismus may be read off.

Deviations are also classed according to the *direction* of the deviating eye, as follows:

Deviating eye turns	Deviation apparent or manifest (squint, strabismus).	Deviation latent (elicited only by special tests); eyes usually perform binocular fixation.
In.	Strabismus convergens (convergent squint, esotropia).	Esophoria.
Out.	Strabismus divergens (divergent squint, exotropia).	Exophoria.
Up.	Strabismus sursumvergens; hypertropia (R. or L., according as R. or L. visual line is higher).	Hyperphoria (R. or L., according as R. or L. visual line is higher).
Down.	Strabismus deorsumvergens; hypertropia (R. or L., according as R. or L. visual line is higher).	Hyperphoria (R. or L., according as R. or L. visual line is higher).

The condition in which there is no tendency to deviation in the primary position is called *orthophoria*.

Etiology of Ocular Deviations; Etiological Classification.—Ocular deviations may be grouped according to their etiology, as follows:

CLASSIFICATION.

- I. Anomalies of the individual muscles :
 - (a) *Under-action*, due to faults in (1) structure, (2) insertion, and (3) innervation.
 - (b) *Over-action*, due to faults in (1) structure, (2) insertion, and (3) innervation.
- II. Anomalies of the association-centers for parallel movements :
 - (a) *Under-action*, producing an impairment of the movements of both eyes either (1) up, (2) down, (3) to the right, (4) to the left, or (5) obliquely (*associated paralysis, conjugate paralytic deviation*).
 - (b) *Over-action*, producing an equal excessive movement or equal spastic deviation of both eyes in the same direction (*associated spasm, conjugate spastic deviation*).
 - (c) *Perverted action*, clonic spasm of associated movements (*nystagmus*).
- III. Anomalies of the center for convergence movements :
 - (a) *Under-action*, convergence-insufficiency, either (1) accommodative or (2) non-accommodative.
 - (b) *Over-action*, convergence-excess, either (1) accommodative or (2) non-accommodative.
- IV. Anomalies of divergence movements :
 - (a) *Under-action*, divergence-insufficiency.
 - (b) *Over-action*, divergence-excess.
- V. Anomalies of sursumvergence :
 - (a) *Under-action*, sursumvergence-insufficiency.
 - (b) *Over-action*, sursumvergence-excess.

SUMMARY.

- I. *Associated parallel deviations* (conjugate deviations) may be due to—
 - (a) Under-action of one of the centers for producing associated parallel movements (conjugate paralysis).
 - (b) Over-action of one of the centers for producing associated parallel movements (conjugate spasm).
- II. *Convergent deviations* (esophoria, convergent strabismus) may be due to—
 - (a) Over-action of one or both internal recti or of the other adductors of the eye (superior and inferior recti).
 - (b) Under-action of the external rectus or of the other abductors (the obliques).
 - (c) Under-action of divergence movements (divergence-insufficiency).
 - (d) Over-action of the center for producing convergence movements (convergence-excess, which in turn may or may not be due to excessive accommodative action).
 - (e) Two or more of the above causes combined.
- III. *Divergent deviations* (exophoria, divergent strabismus) may be due to—
 - (a) Under-action of the internal rectus or of the other adductors (superior and inferior recti).
 - (b) Over-action of the external rectus or of the obliques.
 - (c) Under-action of the center for producing convergence movements (convergence-insufficiency, which, in turn, may or may not be due to insufficiency of accommodative action).

(d) Over-action of divergence movements (divergence-excess).

(e) Two or more of the above causes combined.

IV. *Upward and downward deviations* (hyperphoria, strabismus sursumvergens and deorsumvergens) may be due to—

(a) Over-action of an elevator or depressor muscle.

(b) Under-action of an elevator or depressor muscle.

(c) Under-action or over-action of sursumvergence.

(d) Two or more of the above causes combined.

V. *Mixed forms* (hyperphoria combined with exophoria, hyperphoria combined with esophoria, and esophoria in one part of the field of view combined with exophoria in another) are frequent.

Comitant and Non-comitant Deviations.—Ocular deviations are divided into *comitant*¹ and *non-comitant*. In the former, one eye, even when deviating from the other, always deviates by the same amount, so that the two eyes in all their excursions maintain the same angle with each other. The most typical example of comitant deviations is afforded by the anomalies of the associated parallel movements (associated paralysis, associated spasm, nystagmus).

The ordinary forms of divergent and convergent squint are also generally comitant when they come under observation, although probably for the most part non-comitant in their origin, the comitancy in this case having developed as a result of the evolutionary tendency, described in the next section, by which new compensatory conditions are gradually superadded to the old ones.

In *non-comitant* deviations the deflection of the non-fixing eye keeps varying as the direction of the gaze is shifted, so that the angle between the two visual lines is continually changing. The most marked examples of non-comitance are furnished by disorders (under-action and over-action) of the individual muscles.

Anomalies of convergence and divergence, when uncomplicated, occupy a middle ground between the comitant and the non-comitant deviations. They are comitant in that for any one distance the deflection remains the same whether the eyes are carried up or down or from side to side, but are non-comitant in that the deflection changes in amount in proportion as the object looked at is brought nearer to the eyes or away from them. They are, however, usually classed as comitant.

The *differential diagnosis* between comitant and non-comitant deviations may be thus stated:

Comitant Deviations.

Due to some condition affecting the movements of both eyes equally.

Hence, if simple, are due to derangement of one of the centers which effect the movements of both eyes together (association-centers, centers governing divergence and convergence movements).

Often complex, and then due to compensatory changes (contractures, etc.) gradually developing in an eye that was formerly the seat of a non-comitant deviation.

Non-comitant Deviations.

Due to some condition affecting the movements of one eye more than the other.

Due to an anomaly in structure or insertion of the muscles of one eye, or to an anomaly of the nerves and nerve-nuclei which supply these muscles and which subserve unocular movement.

Usually simple.

¹ The term "comitant," already used by others, has been adopted here (at the suggestion of Dr. H. Knapp), instead of the more usual "concomitant," which is less wieldy, and also not as well formed from an etymological point of view.

Comitant Deviations.

Deviating eye follows the other in all its movements, maintaining the same angle with it. The total range of excursion and total extent of the field of fixation of one eye equal those of the other, but in the deviating eye both are limited in some one direction, and are increased to a like amount in the opposite direction.

Diplopia often absent, or, if present, readily ignored. Patient often fails to recognize double images produced by prisms.

Deviation behind screen, parallax, deviation measured by the phorometer, diplopia (if present), and other symptoms same in amount in all directions of the gaze.

Deviation behind screen of the deflected eye equals that of the non-deflected eye.

Non-comitant Deviations.

Deviating eye lags behind or shoots ahead of the other for certain directions of the gaze. The angle of deviation keeps continually changing. The range of excursion and field of fixation of the deviating eye are either abnormally large or abnormally small in some one direction of the gaze, and in other directions are normal. Total range of excursion abnormally large or small.

Diplopia usually present and apt to persist.

Deviation behind screen, parallax, deviation measured by the phorometer, diplopia, and other symptoms increase markedly and progressively as the eyes are carried in some one direction, and diminish when the eyes are carried in the opposite direction.

Deviation of the two eyes behind the screen unequal, that of the sound eye being the greater if the affected eye is paretic or otherwise limited in action, and that of the affected eye being the greater if the affected eye is the subject of spasm or over-action.

Conversion of Non-comitant into Comitant Deviations.—In non-comitant deviations the deflection is marked for some directions of the gaze, while for other directions the conditions are normal. If, now, some new condition is superadded by which the deflection is made equally marked for all directions of the gaze, the deviation will become comitant. This, in fact, is what tends to take place naturally in all non-comitant anomalies.¹ Thus, a paresis of the right external rectus produces an inward deflection of the right eye, which at the outset is marked only when the eyes are directed to the right. After a time, however, spastic contracture of the right internus develops, which causes an inward deflection of the right eye when the eyes are directed to the left, as well, so that ultimately a condition is produced closely simulating a comitant strabismus convergens.² Again, an exophoria due to a convergence-insufficiency is at first present only when the eyes are directed at near points; but after this condition has persisted for a long time the action of divergence for distance, hitherto normal, becomes excessive (divergence-overaction), and the exophoria becomes marked for distance also. So, too, a periodic convergent squint, in which the eyes are straight for distance, but, owing to convergence-overaction, converge excessively when directed at near objects, is finally converted into a constant squint—*i. e.* becomes marked for distance, too, through the development of an insufficiency of the diverging power or perhaps of an insufficiency of the external recti. In this way a deviation that was comitant only for one range becomes comitant for all.

Subjective Symptoms of Deviations.—The subjective symptoms produced by ocular deviations are—(1) diplopia and blurring of sight, (2) false projection and apparent motion of objects, (3) vertigo, (4) asthenopia, (5)

¹ Except in cases of congenital paralysis or absence of a muscle.

² In fact, probably a number of cases of comitant squint are produced in this very way.

pain in the eyes with conjunctival irritation and blepharitis, (6) headache and neuralgia, and (7) other reflex disturbances, including backache, nausea, impairment of nutrition and energy (sometimes considerable in amount), choreiform spasms, and occasionally graver conditions, such as epilepsy.

1. *Diplopia* is homonymous, heteronymous, or vertical (right or left) according as the deviation is convergent, divergent, or vertical (right or left hyperphoria) (see *ante*, *Table of Diplopia*). Its amount, measured in degrees, is equal to the amount of the deviation present at the time. In ordinary comitant squint (insuperable deviation) it is usually absent, because the image formed by the non-fixing eye is either too indistinct to be noticed or is actually suppressed;¹ in non-comitant squint it is usually present, at least in the earlier stages of the affection; and in superable deviations (heterophoria) it is present at times, although generally overcome by appropriate forced movements of the eyes (see *Table of Diplopia*).

In slight deviations the amount of diplopia is just sufficient to cause overlapping of the double images, producing thereby a considerable *blurring* of the object looked at. This is particularly marked for reading, in which the letters, as they double, become superimposed, and hence appear run together. This confusion of sight is distinguished from that due to an error of refraction by the fact that it disappears as soon as either eye is covered.

In general the slighter degrees of diplopia, and especially those that can be corrected by voluntary effort, are less readily negligible than is a diplopia of larger amount, and hence give rise to more confusion and trouble.

2. *False projection of objects* (*i. e.* the seeing of objects in the wrong place) is particularly noticeable in deviation due to paresis or spasm of an ocular muscle. In this case, when the eye has to use the affected muscle in order to look toward an object, the amount of energy put forth by the muscle is out of proportion to the amount of nerve-impulse sent to it, and hence the patient feels as if the eye had moved much farther or much less than it really has. Thus a patient with a paresis of the right externus when looking at an object situated to his right would regard the object as much farther to the right than it really is, because he has to make a very great effort with the paretic muscle to move the eye as far as he needs to do; and this excessive effort corresponds in his experience to an excessive movement of the eye to the right—*i. e.* to the act of looking at an object that is situated very far to the right. The same thing would take place if he had a paresis of the dextroversion-center (the association-center for turning both eyes to the right). On the contrary, if he had a spasm of the right externus (or of the dextroversion-center), an object situated on his right would appear less far to that side than it really is.

One consequence of this false projection is that objects whose place is thus wrongly conceived of *appear to move* when the eyes are turned or when the patient approaches them. The reason of this is that the amount of displacement of an object from its true situation, produced by false projection, varies with the different positions of the eyes, so that when we change the position (by turning the eyes or by approaching the object) the object appears to be at one moment in its true place, at the next moment out of it—*i. e.* appears to have moved from one place to another.

This apparent movement of objects, together with the diplopia and the unequal strain put upon the eye-muscles, is the cause of the *vertigo* that so often accompanies ocular deviations.

¹ Suppression implies that the image produces its proper impression upon the sensorium, but that the patient by some mental process excludes this impression from his consciousness.

If binocular single vision is lost, the power of appreciating depths and distances is necessarily much impaired (*loss of stereoscopic vision*).

3. The remaining symptoms (*asthenopia, headache, eye-pain, and the various reflex disturbances*) are due to the strain imposed upon the muscles when overcoming a deviation. They are hence more pronounced in heterophoria and in squint of low degree and in intermittent squint (in all of which conditions the patient tries with more or less success to overcome the deviation), than in a marked, constant strabismus, in which, as the deviation is insuperable, the patient makes no attempt to overcome it. Furthermore, the amount of asthenopia and reflex disturbance is roughly proportional to the amount of effort that the patient has to exert in overcoming the deviation. Hence these troubles are more marked in cases of insufficiency than of over-action;¹ and in cases requiring exercise of the comparatively weak diverging power (*e. g.* cases of divergence-insufficiency), and of the still weaker sursumverging power (*e. g.* cases of hyperphoria), than in cases such as those of divergence-excess, that demand exercise of the strong converging action for their compensation. In general, asthenopia is a marked feature of convergence-insufficiency, and eye-pain, with conjunctival irritation and blepharitis, is apt to be associated with the same affection; while headache, neuralgia, nausea, and disturbances of digestion and general nutrition are particularly prone to occur in connection with divergence-insufficiency and the vertical deviations.

CHARACTERS AND DIAGNOSIS OF THE INDIVIDUAL ANOMALIES.

Affections of Individual Ocular Muscles (*Paretic and Spastic Squint*).—**Etiology.**—Over-action or under-action of an ocular muscle may be due to three causes.

(a) Over-development or under-development of the muscle itself (*structural squint and heterophoria*). Thus, congenital non-development of the external rectus occurs, producing a convergent deviation; also congenital non-development of the superior rectus, producing a downward deviation of the eye, which may or may not be associated with ptosis. Again, over-growth of the externus, combined or not with non-development of the internus, is at the bottom of a number of cases of divergent squint or of exophoria; and a similar preponderance in muscular development of the internal recti accounts for many cases of convergent squint.

(b) Faulty insertion of the tendon of the muscle, causing undue laxity or tension of the latter, and giving a point of application for the muscular force, which is more advantageous or is less advantageous than normal (*insertional squint or heterophoria*). Examples of this are—(1) the deflection produced by a tenotomy or an advancement; (2) the over-action of the antagonist of a paralyzed muscle after structural changes (true contracture) have taken place in the former; and (3) the exophoria or divergent squint that develops in childhood as a result of increasing divergence of the orbits, a process which gives the externus a more favorable area of application than the internus. This process, which is a normal feature of development in childhood, may, if occurring in children that originally have the orbits set very close together, abrogate a convergent squint, or even cause the latter to pass gradually into a strabismus divergens.

(c) Paresis or spasm of a muscle due to an affection of its nerve or nerve-nucleus (*innervational anomalies, paretic and spastic squint, and heterophoria*).

¹ Because in insufficiency compensation is effected by means of weakly-acting muscles, and in over-action by means of normal muscles; and it is harder to bring weak muscles up to the normal than to make normal muscles act with extra energy.

The common causes of paresis are tertiary syphilis and its consequences (especially tabes), meningitis (especially tuberculous), pachymeningitis, tumors of the brain and skull, abscess and hemorrhage of the brain, exposure to cold (so-called rheumatic paralysis), traumatism, and hysteria. Paresis may also, although rarely, be due to diphtheria, diabetes, influenza, whooping-cough, and the action of poisons; and slight impairment of power occurs in neurasthenia and other conditions of nervous depression. Spasm, which is much less frequent than paralysis, is due to irritative lesions (meningitis, etc.), chorea, epilepsy, and hysteria; rarely is idiopathic. Spasm also occurs sooner or later in the antagonist of a paralyzed muscle, and ultimately leads to structural changes in the latter (contracture). A false or apparent spasm is the over-action which regularly occurs in the associated antagonist of a paralyzed muscle when an attempt is made to move the latter; the over-action in this case being the result of the excessive stimulus imparted to both muscles. Thus, a patient with a paralysis of the right externus who tries to look to the right makes an excessive effort, which effort causes the right eye to move to the right feebly and the left eye to move to the right very greatly and in an apparently spasmodic way, although, of course, spasm in the true sense of the word is not present here at all, since the eye is simply reacting normally to an excessive stimulus.

One or several muscles may be affected. In insertional and structural deviations isolated affections are frequent, and the muscles most apt to be involved are the external, internal, and superior recti. In innervational deviations, if but one muscle is affected, this is usually the external rectus (*abducens paralysis* or *spasm*), although isolated paralysis of the superior oblique (*trochlear paralysis*) is not uncommon. Isolated paralysis of the other muscles is less often met with, but combined paralysis of some or all of the muscles supplied by the third nerve (*oculomotor paralysis*) is frequent. Complete oculomotor paralysis causes loss of power in four out of the six exterior muscles of the eyeball, and also in the levator palpebræ (causing ptosis), the sphincter iridis (*iridoplegia*), and the ciliary muscle (*cycloplegia*). In some cases, caused generally by syphilis or by the action of poisons such as atropin, the paralysis is confined to the sphincter iridis and the ciliary muscle (*ophthalmoplegia interna*); in others to the sphincter iridis, producing mydriasis without any other symptoms; in others, especially when due to diphtheria, to the ciliary muscle, producing paralysis of accommodation alone; and in still other cases these muscles are exempt, but some or all of the exterior muscles of the eyeball are paralyzed (*ophthalmoplegia externa*). In rare cases all the muscles of the eyeball, exterior and interior, are paralyzed at the same time (*ophthalmoplegia totalis*).

Symptoms.—The symptoms of muscular under-action and over-action are—(1) limitation or excess of movement of the affected eye in some one direction—*i. e.* as the two eyes move together in that direction one of the two lags more and more behind the other, producing a constantly increasing deviation. This symptom gives rise to all the others—namely, (2) diplopia, (3) false projection of objects seen with the affected eye, (4) apparent movement of such objects when the patient approaches them, and (5) vertigo. The explanation of these symptoms has already been given. The characteristic feature about all of them is that they increase as the eyes are carried in some one direction—*increase*, namely, in that position of the eyes in which the affected muscle when normal acts most effectively in moving the eye (see *Table*, p. 502), and *decrease* as the eyes are carried in the contrary direction. For example, in an affection of the right superior oblique the diplopia, vertigo,

etc. are absent when the patient looks up, begin to appear when he looks down, increase rapidly when he looks down and to the left, and are much less marked when he looks down and to the right; because, in the first place, the superior oblique, being a depressor, acts normally only when the eyes are directed down, and because, in the second place, it acts much more energetically as a depressor when the eyes are directed down and in.

This characteristic feature of these conditions gives rise to another symptom—(6) namely, altered position of the head, the patient in each instance holding it in such a way as to prevent the development of diplopia, etc. Thus, if the deviation is such that diplopia occurs when the eyes are turned to the right, he gets over the difficulty by turning his head to the right, so that the eyes themselves are directed to the left.

The symptoms vary in intensity from a slight, transient diplopia, elicited only by the different tests for heterophoria, to the complete immobility produced by total paralysis.

In ophthalmoplegia interna (7) mydriasis and (8) paralysis of accommodation will occur; and in complete oculomotor paralysis both these symptoms together with (9) ptosis.

Course and Prognosis.—Structural deviations, particularly if congenital, show little tendency to increase or decrease. Insertional deviations are apt to increase, except when the result of a tenotomy or advancement, in which case they usually decrease because of the contraction that takes place in the process of healing.

Paretic or spastic deviations may recover spontaneously or as the result of treatment. This is always the case in hysterical affections, and is the rule in the cycloplegia due to diphtheria. On the other hand, in diphtheritic paralyzes of the external muscles and in paralyzes due to exposure to cold the condition often persists for a long time or even permanently; and ophthalmoplegia interna, except when due to the action of drugs, is usually incurable.

In chronic paralyzes the prognosis is uncertain, the condition being sometimes recovered from, often remaining stationary, and in yet other cases advancing progressively. The tendency to advance is particularly marked in the slowly developing paralyzes of nuclear origin affecting isolated muscles, and especially in the variety of paralysis known as ophthalmoplegia externa (see page 511). In these cases one muscle after another is, in the course of months or years, successively involved (*progressive ophthalmoplegia*), the process often extending to other centers besides the nuclei of the eye-muscles, and causing death through involvement of the respiration or other vital action.

Paralyzes of sudden development, on the other hand, do not usually show this tendency to advance, and often indeed disappear completely. It is, however, to be remarked that those cases that get well rapidly and spontaneously are particularly apt to be the precursors of tabes, disseminated sclerosis, and general paresis.

To two classes of acutely developing ophthalmoplegia, however, this grave prognosis does not apply. In one (*recurrent ophthalmic migraine*) a total oculomotor paralysis, preceded usually by violent migraine, recurs at more or less periodical intervals, and, after lasting for a day or two in some cases and two or three months in others, disappears almost or quite completely. In the other (*transient bilateral ophthalmoplegia*) a paralysis, usually, but not always, affecting all the ocular muscles and always bilateral, develops rapidly, and disappears completely after lasting one or two months.

Under-action of an ocular muscle, whether due to paralysis or not, after lasting for a time leads to over-action, and finally to permanent *contracture* of the opposing muscle in the same eye. In like manner, continuous over-action of a muscle leads to enfeeblement of its antagonist. The deviation in both instances is thus gradually converted into a comitant one (see page 508). Contracture of the opponent does not, however, usually take place in congenital paralysis.

The symptoms, especially the false projection and vertigo, gradually grow less pronounced as the patient accommodates himself to his new experiences. The diplopia often remains for a very long time, and may even persist after the deviation has become comitant.

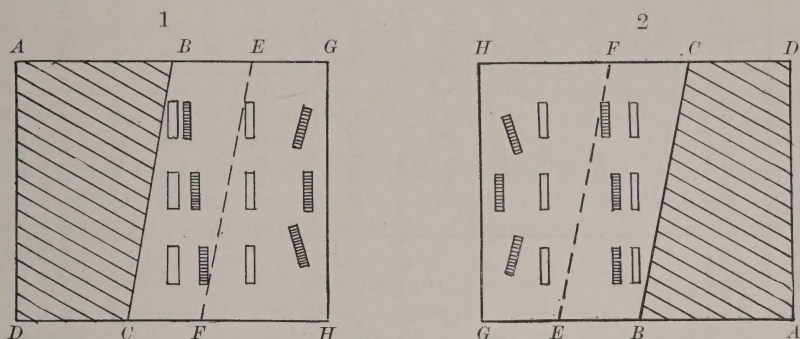


FIG. 320.—1, right external rectus; 2, right internal rectus.

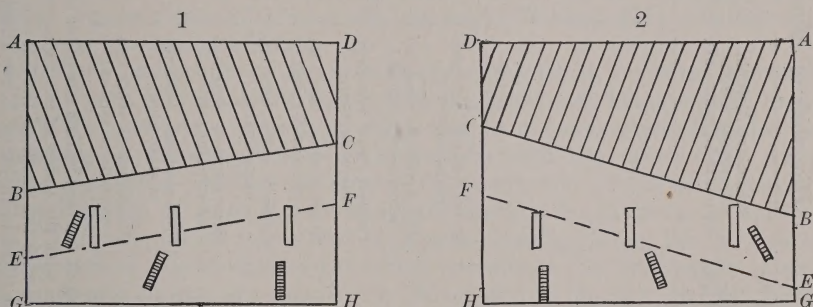


FIG. 321.—1, right inferior rectus; 2, right superior oblique.

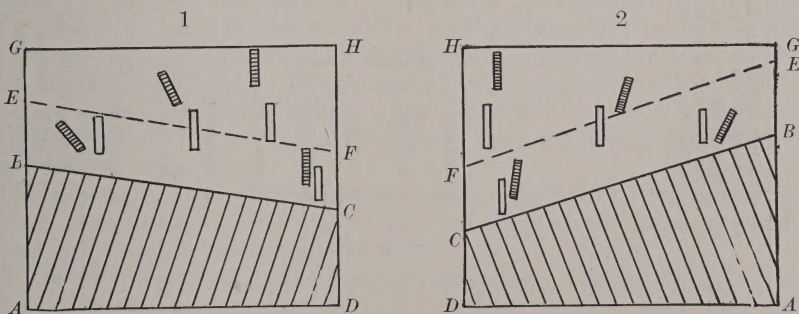


FIG. 322.—1, right superior rectus; 2, right inferior oblique.

FIGS. 320-322.—Scheme of double images in paralysis of the ocular muscles (modified from Mauthner and Berry): $A G H D$, field of binocular single vision of normal eyes; shaded area, $A E C D$, field of binocular single vision in complete paralysis; unshaded area, $B G H C$, field of double vision in complete paralysis; area, $A E F D$, field of single vision in partial paralysis; area, $E G H F$, field of double vision in partial paralysis. Shaded image is that belonging to the right eye.

Diagnosis of Muscle Affected.

Characteristic diplopia.	Diplopia and the discrepancy in the position of the eyes, ¹ Increasing as the eyes are carried to		Subsidiary diplopia (frequently absent or not to be made out).	Subsidiary diplopia, increasing as eyes are carried to	Head turned to	Diagnosis.	
						Under-action (paresis) of	Or over-action (spasm) of
Homonymous	R.	L.	. . .	. . .	R.	R. externus.	L. internus.
Homonymous	L.	R.	. . .	. . .	L.	L. externus.	R. internus.
Crossed	R.	L.	. . .	. . .	R.	L. internus.	R. externus.
Crossed	L.	R.	. . .	. . .	L.	R. internus.	L. externus.
Right ²	L. and up.	R.	Crossed (and heteronymous torsion). ⁵	R.	L. and up.	L. superior rectus.	R. inferior oblique.
Right	R. and up.	L.	Homonymous (and homonymous torsion). ⁴	L.	R. and up.	L. inferior oblique.	R. superior rectus.
Left ³	R. and up.	L.	Crossed (and heteronymous torsion). ⁵	L.	R. and up.	R. superior rectus.	L. inferior oblique.
Left	L. and up.	R.	Homonymous (and homonymous torsion). ⁴	R.	L. and up.	R. inferior oblique.	L. superior rectus.
Right ²	R. and down.	L.	Crossed (and homonymous torsion). ⁴	L.	R. and down.	R. inferior rectus.	L. superior oblique.
Right	L. and down.	R.	Homonymous (and heteronymous torsion). ⁵	R.	L. and down.	R. superior oblique.	L. inferior rectus.
Left ³	L. and down.	R.	Crossed (and homonymous torsion). ⁴	R.	L. and down.	L. inferior rectus.	R. superior oblique.
Left	R. and down.	L.	Homonymous (and heteronymous torsion). ⁵	L.	R. and down.	L. superior oblique.	R. inferior rectus.

¹ Evidenced by the lagging of one eye behind the other and by the degree of deviation behind the screen.² That is, vertical diplopia with the image of the right eye below (or left eye above).³ That is, vertical diplopia with the image of the left eye below (or right eye above).⁴ That is, image of R. eye tilted to R. (or of L. eye tilted to L.).⁵ That is, image of R. eye tilted to L. (or of L. eye tilted to R.).

Diagnosis.—The diagnosis of *the muscle affected* may in the case of (1) under-action or over-action of a *single muscle* be made from the double images by means of the table on page 514. (See also Figs. 320–322.)

2. A diplopia increasing in more than one direction indicates an *affection of more than one muscle*, the diagnosis of the specific muscles being made from the table. *E. g.* a right diplopia increasing both in looking up and to the left and up and to the right indicates weakness of the left superior rectus and the left inferior oblique; and a left diplopia increasing in looking up and to the right, combined with a right diplopia increasing in looking up and to the left, indicates a paralysis of both superior recti or a paralysis of one superior rectus, combined with spasm of the inferior oblique in the same eye.

3. Crossed diplopia (with the image of the affected eye somewhat below), combined with inability of the eye to move upward, inward, or to any great extent downward, although it can still move out well, indicates *oculomotor paralysis*. The latter is complete if there are also ptosis, mydriasis, and paralysis of accommodation.

Convergent Deviations; Esophoria and Convergent Squint.—

A convergent deviation may exist in all degrees, from an esophoria of 2° or 3° , elicited only by careful tests with the phorometer, to a constant convergent squint. In any case it may be due to—

1. Weakness of one or both externi or over-action of one or both interni, or to both these causes combined (*muscular deviation*). The weakness or over-action, which may be structural, insertional, parietic, or spastic in origin, produces a more or less non-comitant deviation having the characters already given of a purely muscular anomaly (see pages 510 and 511). Briefly stated, these characters are as follows:

Outward movements of one or both eyes diminished, or inward movements of one or both increased, the increase in the latter case being equally marked whether the eye turns inward in obedience to a convergence-impulse, or in performing an associated parallel movement with the other eye. In performing associated parallel movements the restriction of outward movement and the increase of inward movement are marked for distance as well as for near. The amount of restriction or increase usually differs for the two eyes, and the sum of the inward and outward movements, or total range of excursion, is greater in one eye than in the other, and in one eye, at least, is absolutely greater or less than normal (enlargement or contraction of the field of fixation). Degree of convergence or esophoria (as measured by the diplopia, deviation behind the screen, parallax, and phorometer) is not materially different for distance and near, but changes noticeably as the eyes are moved to the right or to the left. Near-point of convergence usually closer to the eyes than normal, but often nearer when the object looked at is carried from one side obliquely inward toward the nose than when it is carried inward from the other side.

The determination of the specific muscle affected can by means of the table on page 514 be deduced from the direction of the gaze in which the diplopia or deviation increases the most.

2. *Convergence-excess.*—The signs of this are—

For distance, convergence or esophoria less than for near, and usually slight. Prism-divergence (so-called abduction) normal or at least not disproportionately low (*i. e.* with an esophoria of 3° – 4° , not below 4°). Prism-convergence (adduction) readily performed. Associated parallel movements normal and equal in the two eyes. Total range of excursion normal in both eyes.

For near-points, convergence or esophoria marked (by all tests). Convergence near-point excessively close to the nose, and equally so whether the object looked at is carried toward the nose from the right or from the left. Eye moves farther inward in response to a convergence-impulse than when executing a parallel movement in conjunction with the other eye. Excess of inward movement same for each eye.

Convergence-excess is often due to excessive accommodative action exerted to overcome hyperopia or astigmatism, the association between accommodation and convergence being so intimate that one function can hardly be brought into play without bringing in the other with it. In this accommodative convergence-excess the signs above enumerated will tend to disappear upon the instillation of atropin and the continuous wearing of the proper correcting glasses. But cases of non-accommodative convergence-excess also occur, and in these glasses afford no relief.

3. *Divergence-insufficiency*.—The signs of this are—

For distance, convergence or esophoria marked. Prism-divergence (abduction) disproportionately low, absent, or even negative (*i. e.* there is homonymous diplopia that the patient cannot overcome, except when prisms, base out, are placed before the eye). Prism-convergence (adduction) normal or often subnormal. Associated parallel movements and range of excursion equal in both eyes, and normal or nearly so.

For near-points, convergence or esophoria slight or absent or even replaced by exophoria. Convergence near-point not abnormally close to the nose, and about equally far from the latter when the object looked at is carried inward from the right or from the left.

In rare cases the insufficiency may be so great as to constitute an actual *divergence-paralysis* (Parinaud, Uhthoff, Straub). These cases are characterized by homonymous diplopia for distance, with marked convergent squint when the eyes are directed straight ahead; both the diplopia and the convergence diminishing progressively as the eyes are carried to the right or to the left. Such cases may be secondary to an abducens paralysis.

4. A convergence-excess which has lasted a long time is regularly followed by a divergence-insufficiency, and a divergence-insufficiency of long standing is followed by a convergence-excess. The *mixed form* thus produced is characterized by marked esophoria (and often by homonymous diplopia) for both distance and near, excessive approximation of the convergence near-point, and limited, absent, or negative prism-divergence (abduction). The constant over-action of the convergence seems to lead to actual over-development of the interni, and the under-action of the divergence to actual insufficiency of the externi, thus causing still further increase of the deviation. When the deviation becomes too great for the patient to overcome, so that binocular vision can no longer be maintained, a squint develops, which, at first intermittent, afterward becomes constant.

This conversion of an esophoria into a convergent squint is favored by the presence of any condition (amblyopia of one eye, anisometropia) which renders binocular vision of little value.

A convergent squint thus developed is prone to increase. But in children such a squint often diminishes and sometimes disappears, owing to the tendency that the eyes have to become divergent during the age of growth (see page 510).

The symptoms of convergent deviations are—homonymous diplopia (especially in cases that are passing from the state of a heterophoria to that of a squint); unilateral amblyopia and loss of stereoscopic vision (in true squint);

and asthenopia, headache, neuralgia, and nutritive disturbances in esophoria proper (especially in divergence-insufficiency).

Divergent Deviations; Exophoria and Divergent Squint.—A divergent deviation, whether a slight exophoria or a marked divergent squint, may be due to—

1. Weakness of one or both interni or over-action of one or both externi, or to both these causes combined (*muscular deviation*). The weakness or over-action may be structural, insertional, or innervational, and produces, particularly when unilateral, a more or less non-comitant deviation having the following characters, indicative of a purely muscular anomaly (see pages 510 and 511).

Outward movements of one or both eyes increased or inward movements of one or both diminished, the diminution in the latter case being equally marked whether the eye turns inward in obedience to a convergence-impulse or in performing an associated parallel movement with the other eye. In performing associated parallel movements the restriction of inward movement and the increase of outward movement are marked for distance as well as for near. The amount of restriction or increase usually differs for the two eyes; and the sum of the inward and outward movements, or total range of excursion, is greater in one eye than in the other, and in one eye, at least, is absolutely greater or absolutely less than normal. Degree of divergence or exophoria (as estimated from the diplopia, deviation behind the screen, parallax, and phorometer) not materially different for distance and near, but changes noticeably as the eyes are carried to the right or to the left. Near-point of convergence often more remote from the eye than normal, but may be much farther when the object looked at is carried from one side obliquely inward toward the nose than when it is carried obliquely inward from the other side.

The determination of the specific muscle affected may be deduced (by means of the table on page 514) from the direction of the gaze in which the crossed diplopia or the exophoria increases the most.

2. *Convergence-insufficiency*.—The signs of this are—

For distance, but slight divergence or perhaps orthophoria. Prism-divergence (abduction, so called) not usually above 10° and often subnormal (6°). Prism-convergence (adduction) often performed with difficulty even after a number of trials. Associated parallel movements and total range of excursion normal or nearly so, and equal in both eyes.

For near-points, exophoria of 6° and upward and divergence marked (by all tests). Convergence near-point over $3''$ (often from $6''$ to $10''$) from the nose, and equally distant from the latter whether the object looked at is carried toward the nose from the right or from the left. Maintenance of convergence for more than a moment difficult. Eyes turn farther inward in performing associated parallel movements than in performing convergence movements (*i. e.* when the convergence near-point is reached either eye can turn still farther inward, but the other eye will then diverge). Limitation of movement inward same for each eye.

In some cases the insufficiency is so great as to constitute an actual *convergence-paralysis* (Parinaud, A. Graefe). The characteristic sign of this is that, while either eye can move inward to a normal degree, provided the other eye moves outward, it cannot move inward at all in response to an impulse of convergence. Hence, the convergence near-point, instead of receding to only $6''$ or $7''$, is situated a yard or more from the eyes, and when the object looked at is brought nearer than this, insuperable crossed diplopia develops.

Owing to the intimate relation existing between accommodation and convergence, those who use their accommodation but little in looking at near-points will tend to converge less than they should. Hence, convergence-insufficiency occurs in myopes who wear no glasses for near, and also in hyperopes and presbyopes who wear too strong convex glasses for near. This *accommodative insufficiency* will disappear if the myope is made to wear concave glasses for near, and if, in the other conditions, the strength of the convex glass is lessened. But a non-accommodative convergence-insufficiency, not corrigible in any such way, also exists.

3. *Divergence-excess*.—The signs of this are—

For distance, exophoria or divergence marked. Often spontaneous crossed diplopia. Prism-divergence (abduction) high (in pure cases disproportionately so—*i. e.* with an exophoria of 4° or 5° there may be a prism-divergence of 13° or 15°). Prism-convergence (adduction) usually normal. Associated parallel movements and range of excursion equal in both eyes and normal or nearly so.

For near-points, exophoria or divergence slight. Convergence near-point and power of maintaining convergence normal. Convergence near-point same whether the object looked at is carried from the right or from the left obliquely toward the nose.

4. A convergence-insufficiency which has lasted a long time is regularly followed by a divergence-excess, and a divergence-excess which has lasted a long time by a convergence-insufficiency. The *mixed form* thus produced is characterized by marked exophoria (or divergent squint) and often by crossed diplopia for both distance and near, excessive prism-divergence (abduction), and marked recession of the convergence near-point. Here, as in esophoria, the constant over-action of the divergence produces apparently an actual over-development of the externi, and the under-action of the convergence an actual insufficiency of the interni, thus causing still further increase of the deviation. Here also, when the deviation becomes too great for the patient to overcome, so that binocular vision can no longer be maintained, a squint develops, at first intermittent, afterward constant. As in the case of the convergent deviations, the presence of anisometropia or unilateral amblyopia favors this conversion of an exophoria into a divergent squint.

A divergent squint thus developed usually increases.

The symptoms of divergent deviations are—crossed diplopia (especially in cases that are passing from the state of a heterophoria to that of a squint); unilateral amblyopia and loss of stereoscopic vision in cases of confirmed squint; and asthenopia and conjunctival irritation with pain in the eyes in exophoria (particularly in convergence-insufficiency). Headache is less frequent and other symptoms are rather rare.

Vertical Deviations; Hyperphoria and Vertical Squint.—Vertical deviations, whether superable (hyperphoria) or productive of an actual squint, are either comitant or non-comitant.

1. *Non-comitant hyperphoria* is occasioned by under-action or over-action of one or more of the elevators or depressors. As in this case the deviation (determined by the vertical diplopia, deflection behind the screen, parallax, and phorometer) varies noticeably in different directions of the gaze, the diagnosis of the specific muscle affected can readily be made from the table on page 514. In a number of these cases the hyperphoria is apparently due to spasmodic action of the muscles, since it changes in amount from one examination to another, and after a time disappears altogether.

2. In a *comitant hyperphoria* the deviation (determined by the diplopia,

deflection behind the screen, parallax, and phorometer) remains sensibly the same in all directions of the gaze. Some of these cases may be due to a vertical separation of the visual axes, due to excessive sursumvergence, but most are probably examples of a non-comitant hyperphoria which has become comitant through the agencies already described (see pages 508, 513). In this case the diagnosis of the muscle affected is usually no longer possible.

The deviation is often slight (only 1° or 2°). When slight it can be overcome by the action of sursumvergence. In well-marked cases it will generally be found that there is a difference of 1° or more between the right and left sursumvergence, the former predominating in right hyperphoria and the latter in left hyperphoria.

Hyperphoria does not, in general, show any great tendency to increase, and cases of actual vertical squint—*i. e.* of a vertical deviation so great that binocular fixation can no longer be performed, and but one eye fixes—are rare. Such a squint is called a *strabismus sursumvergens* if the deviating eye stands higher, and *strabismus deorsumvergens* if it stands lower, than the one which regularly performs fixation.

The symptoms of vertical deviations are vertical diplopia, blurring of binocular vision, asthenopia, headache, neuralgia, nausea, vertigo, disturbance of nutrition, choreiform twitchings, and other evidences of reflex trouble. The symptoms in general are more frequently present, more varied in character, and more severe in this form of ocular deviation than in any other.

Associated Parallel Deviations.—Associated parallel deviations comprise—

1. **Associated Paralysis and Spasm.**—Paralysis of the movements of both eyes to the right or of both eyes to the left frequently occurs in destructive lesions of the brain, and especially in apoplexy. This condition is not due to paralysis of the externus of one eye and the internus of the other, since the internus may still act in movements of convergence, but it is due to the involvement of the higher (association) center governing the movement of both eyes to the right or to the left (dextroversion and sinistroversion). Paralysis of the movements of both eyes up and of both eyes down has also been observed, but is rare.

Spasm of the associated parallel movements occurs in irritative lesions of the brain involving the association centers or tracts, and also in hysteria. It produces a spastic deviation of both eyes in the same direction (right, left, up, down, or obliquely).

2. **Nystagmus.**—Nystagmus consists in a very rapid oscillating movement of the eye in some one direction. Almost invariably both eyes take part in the movement, the oscillations of the two being equal and in the same sense. According to the direction of the movement nystagmus is called horizontal, vertical, rotary (when both eyes roll like wheels in the same direction), or mixed (when oscillations of two different kinds are combined). Horizontal nystagmus is much the most frequent form.

Nystagmus is due to alternate discharges from the association centers for parallel movements. For example, in horizontal nystagmus there is first a discharge from the center for turning both eyes to the right (dextroversion center), followed at once by a discharge from the center for turning the eyes to the left (sinistroversion center). In those who are subject to it it is often set up by the attempt to fix the eyes on an object or to turn them in some special direction. It occurs—

(a) As a result of visual defects (such as cataract, opacities of the cor-

nea, diseases of the retina and choroid, and albinism), which, being either congenital or acquired soon after birth, have prevented the patient from ever seeing well or from learning to direct his eyes properly.

(b) As a late acquired affection in disseminated sclerosis, in hereditary ataxia, and in hemorrhage, degeneration, inflammation, and tumors of the meninges, cord, and brain (especially the cerebellum). A special acquired form occurs in miners (*miner's nystagmus*), who work by a bad light and with their eyes in a strained position. Nystagmus may also be produced by a rapid rotation of the body or any other cause affecting the functions of the semicircular canals (auditory disease).¹

In some of the forms acquired late in life, particularly miner's nystagmus, the oscillation of the eyes produces an apparent movement of objects looked at, with consequent vertigo. Otherwise the disease causes no symptoms.

Nystagmus occasionally disappears spontaneously or as a result of the removal of the optical defect that caused it; and miner's nystagmus may disappear on removal of the patient from the hurtful conditions under which he lives. Otherwise the condition is not susceptible of amelioration.

Treatment of Ocular Deviations.—The first indication to be fulfilled where possible is—1, to *remove the cause* of the deviation. Hence in paralysis or spasm due to syphilis, meningitis, periostitis, and exudative processes in general we use iodids and mercurials; in rheumatic paralyses we employ the iodids, salicylates, and diaphoresis; in diabetic paralyses, the appropriate diet; and in miner's nystagmus we remove the patient from his hurtful surroundings.

2. The next indication to be fulfilled in all cases causing symptoms is to *correct the refraction*. Such correction will in many cases (*e. g.* those of accommodative convergence-excess and insufficiency) remove the deviation itself; in others, while having no effect upon the deviation, it will do away with the symptoms. In esophoria (particularly in convergence-excess) the total amount of hyperopia and astigmatism (determined under a mydriatic) should be prescribed and the glasses worn constantly. In exophoria (particularly convergence-insufficiency) the myopia present should be fully corrected, and the concave glasses worn for near as well as for distance. On the other hand, it is often proper to more or less under-correct hyperopia or presbyopia coexisting with convergence-insufficiency.

In ophthalmoplegia interna it is often necessary to prescribe a convex glass for the affected eye to supplement its lost accommodation.

3. Exercise, tonics, and other *corroborant measures* are frequently required in debilitating affections, neurasthenia and hysteria, which by causing a temporary enfeeblement of the muscles either produce a deviation directly or, in case one is already present, interfere with its proper compensation.

4. The *bromids* may be of use in certain cases of spasm. Other remedies, such as *strychnin*, *electricity*, etc., which are supposed to act directly upon the muscles or nerves, are of little value, except in so far as they improve the general nutrition. The same may be said with even more force of electricity and eserine in ophthalmoplegia interna.

5. Exercise of the prism-convergence (so-called adduction) with *prisms*, base out, is often useful in exophoria (particularly convergence-insufficiency), but often fails. Exercise with prisms, base in, in esophoria is of no service.

¹ Nystagmus-like twitchings of a muscle (especially a paretic muscle) may also occur when the latter is carried to the extreme limit of its excursion, but this is not nystagmus in the proper sense of the term.

Prisms for continuous wear may be useful, particularly in slight and stationary vertical deviations. Their employment in lateral deviations is to be avoided, except as a temporary measure, since prisms, base in, tend to produce convergence-insufficiency, and prisms, base out, a convergence-excess, so that in both cases they ultimately increase the deviation which they are designed to correct.

6. The muscles may be exercised, not only by means of prisms, but also by making forced movements of the eyes in different directions, up, down, right, and left; by making forced movements of convergence in looking at near objects; by forcing the eyes to overcome a natural diplopia of small amount; and by forcing the eyes to move so as to unite the images of two objects which are some distance apart. These *orthoptic exercises*, as they are called, should not be kept up for more than a few minutes at a time, but may be repeated several times a day.

7. An *operation* is to be done only when the symptoms are marked and when it is apparent that all other measures will fail. In structural and insertional muscular anomalies an operation is generally indicated, and does good service. In parietic and spastic deviations it is indicated only when we are assured that the condition has become stationary. In convergence and divergence anomalies it is usually indicated when the deviation is marked and when correction of the refraction after long trial has afforded no relief. In all cases the rule is to perform tenotomy of an over-acting muscle and advancement of one that is under-acting, provided always that the latter is capable of acting at all. The specific operations to be employed are—

(a) In esophoria (or convergent squint), when due to over-action of one or both interni or to convergence-excess, tenotomy of one or both interni; when due to weakness of the externi or to divergence-insufficiency, advancement of one or both externi combined, especially if there is over-action of convergence or over-action of the interni, with tenotomy of the latter.

(b) In exophoria, when due to over-action of one or both externi or to divergence-excess, tenotomy of the externi; when due to convergence-insufficiency or to actual insufficiency or paresis of one or both interni, advancement of the latter, combined, if necessary, with tenotomy of the externi.

(c) In non-comitant hyperphoria, when due to weakness of the superior or inferior rectus, advancement of the weak muscle; when due to over-action of the superior or inferior rectus, tenotomy of the over-acting muscle; when due to weakness (paresis) of the superior oblique, tenotomy of the inferior rectus of the other eye; when due to over-action of the superior oblique, advancement of the inferior rectus of the other eye; when due to weakness of the inferior oblique, tenotomy of the superior rectus of the other eye; and when due to over-action of the inferior oblique, advancement of the superior rectus of the other eye. A comitant hyperphoria is generally best remedied by tenotomy of the superior rectus of the higher eye.

In performing either a tenotomy or an advancement the precise amount of the deviation should be measured (when possible by the phorometer) before and during the operation, the latter being done in successive steps, and its effect gradually increased until just the desired amount of correction is obtained. As the ultimate effect is somewhat less than the primary, it is advisable in operations upon the lateral muscles¹ (especially advancements)

¹ Operations upon the superior and inferior recti, if carefully performed, do not need to be overdone.

to produce an over-effect of about 3° .¹ An exception is in the convergent squint of young persons, in which we prefer to leave a slight amount of convergence, so as to prevent a possible over-correction later, and in large deviations, in which the best plan is to divide the operation between the two eyes.

In the author's experience the best results are secured if the tenotomy is performed by the open method, the incision being made in the middle of the tendon, near its insertion, and carried gradually up and down until the tests show that the fibers are sufficiently detached. A bandage is not applied in the case of a simple tenotomy, and the patient is encouraged to use his eyes for distant vision directly after the operation, for then the directive influence of binocular fixation, exerted upon the tissues when they are still plastic, tends to make the eyes assume their proper position with regard to each other.² In advancement a bandage is required to prevent sudden movements of the eye, which would produce loosening of the sutures.

If an excessive over-correction is produced, the surplus should be at once removed by inserting a suture and making the proper traction.

¹The operation, however, should not be carried so far as to reduce the diverging power (abduction) to below 5° or increase it to above 12° .

²This tendency may be reinforced by exercises with prisms performed systematically while the tissues are healing.

INJURIES AND DISEASES OF THE ORBIT.

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CONGENITAL ANOMALIES.

CONGENITAL faults in the development of the orbits have been described in all degrees, from trifling defects in limited portions of their bony walls to complete absence of these cavities, one or both; in the latter case the structures they are designed to enclose are also wanting. In the lesser defects the orbital contents may be modified in various ways. Such modifications as affect the eyeballs are of special interest. Of these there are four well-known conditions. They are—anophthalmos, microphthalmos, megalophthalmos, and cyclopia. The first three of these are not, however, necessarily associated with anomalies in the construction of the orbits. Although congenital defects of this class are usually bilateral, one-sided faults are by no means uncommon.

Anophthalmos.—Congenital absence of both eyes is a rare condition (still more rarely is this condition unilateral—*monophthalmos*). In most of these cases the palpebral fissure has been found closed or very narrow, the conjunctival sac small, of a pale-red color, and the eyeball totally absent or only represented by a soft, irregular flesh-like mass. Several or all of the extrinsic ocular muscles have been found in connection with this rudimentary mass. The orbital cavities are always smaller than normal, and the *adnexa* of the eye, when present, are small and ill-developed. The faulty development in these cases is not confined to the orbits and their contents, but involves also the chiasma, optic tracts, corpora quadrigemina, and sometimes adjacent parts of the cerebrum.

A few instances of monolateral anophthalmos have been observed. In one of these the single eye was normally developed. This anomaly is explained by failure of the primary optic vesicle to bud from the anterior primary encephalic vesicle, or, having budded, it has failed to form a secondary optic vesicle. In every case the eye was properly situated, even when very imperfect—a feature which justifies the use of the term *monophthalmos* in describing this deformity, and distinguishes it from the more common monstrosity known as *cyclopia*.

Cyclopia.—This anomaly is a fusion of both orbits and their contents, with a single eyeball situated in the middle line just above the ordinary position of the root of the nose. This single eye may be larger or smaller than normal for the general development, but always shows unmistakable evidence of an imperfect fusion of the two eyes. The same is true of the *adnexa* of the eye. In all such cases the ethmoid is absent or only rudimentary. The olfactory nerves are wanting, and the cerebrum is so imperfectly formed that,

although some cyclops have been living when born, all that the writer has been able to find records of have died within a very short time after birth.

Microphthalmos.—Eyes which at birth are considerably smaller or larger than normal are seldom, if ever, sufficiently normal in other respects to admit of useful vision. These peculiarities are probably the result of some pathological process *in utero*, rather than a mere arrest or excess of development. Either condition may be found in one or both eyes.

In microphthalmos the whole globe is uniformly spherical, sometimes flattened below; the cornea is usually very much smaller than normal, its margins ill-defined, and curvature of the same radius as the adjacent sclerotic; the anterior chamber, iris, and pupil are correspondingly diminished. The palpebral fissure is narrow, and the lids, unsupported by the globe, are partly deprived of their ordinary functions. The changes in the interior of the globe have not been fully studied. According to Manz, they are often of a degenerative character, such as occur in phthisis bulbi from other causes. In the higher grades of microphthalmos vision is, of course, entirely wanting.

Megalophthalmos is a rare congenital anomaly in which the cornea and anterior chamber are larger than normal (*hydrophthalmos anterior*). The explanation of this is probably to be found in some intra-uterine pathological condition in which the intra-ocular tension has been increased at a time when the cornea possessed less resisting power than the sclerotic, and therefore became distended, whilst the posterior segment of the eyeball remained relatively unaffected in its development (see also pages 329 and 385).

DISEASES OF THE ORBIT.

A glance at Fig. 323 shows that the eyeball is rather loosely slung in the conical bony cavity of the orbit, well toward its anterior part. The bony walls

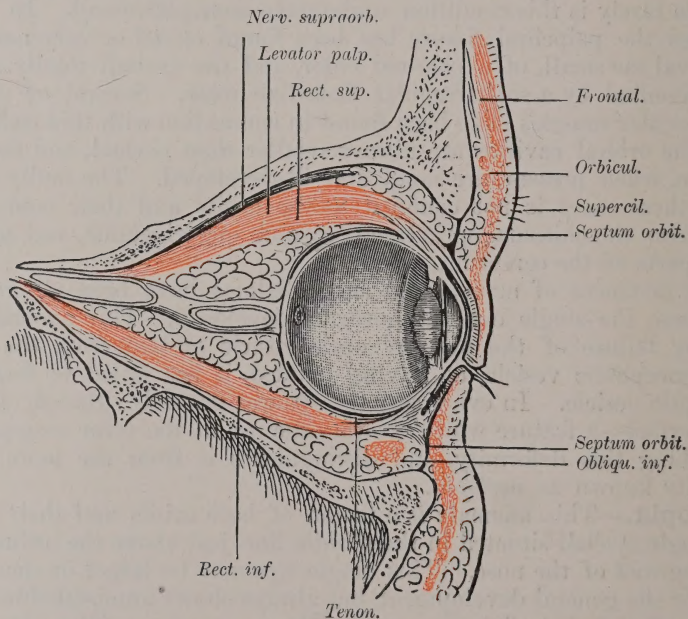


FIG. 323.—Sagittal section of orbit (De Wecker and Landolt).

of this hollow cone are so unyielding that any considerable augmentation of its contents or encroachment from without will have the effect of displacing the

eyeball. The displacement will naturally be greatest in the direction of least resistance, which, in a general way, is obviously forward.

General Symptoms of Orbital Disease.—Most of the pathological conditions met with in the orbit either increase its contents or come from encroachment upon some part of its walls; hence a more or less forward displacement of the eyeball—*proptosis*—is the most usual sign of disease of the orbit.

In the normal state the eyeball is freely movable in every direction by means of the three pairs of ocular muscles, each one of which is situated entirely within the orbit, and therefore liable to loss of function from changes in the tissues surrounding them; hence another common sign of orbital disease is *alteration in the mobility of the eye*. Inflammatory processes or morbid growths, which cause infiltration of the tissues surrounding the muscles, are especially liable to result in fixation of the eyeball. Periostitis, even of a limited extent, at the apex of the orbit may have a similar effect by pressure upon the motor nerves as they pass through the Sylvian fissure, thus causing a paralytic immobility.

On the other hand, a high degree of proptosis, caused by non-infiltrating growths arising within the orbit or projecting into it from adjacent parts, is compatible with free mobility of the eyeball, as in certain orbital cysts and other encapsuled new growths. Only in case of one-sided exophthalmos can a fairly accurate estimate of the displacement be made by comparison with the position of the eyeball in the normal orbit. If the displacement is bilateral, its degree is a matter of conjecture, and allowance must be made for the fact that a wide palpebral fissure simulates *exophthalmos*, whilst a narrow fissure may simulate the opposite condition or *enophthalmos*.

The differential diagnosis of orbital disease will be greatly facilitated by a careful consideration of the following less constant signs:

(1) *Redness, swelling, and edema of the lids*, especially conspicuous in the inflammatory affections of the cellular tissue of the orbit.

(2) *Chemosis of the conjunctiva*, either general or localized, over a certain portion of the globe nearest the area of disease.

(3) *Fluctuation* is likely to be present when an abscess of the orbit has formed, but cannot always be made out with certainty.

(4) *Pain*, intensified when the patient attempts to rotate the eyeball or when it is pressed backward, and the surroundings are palpated by the surgeon. Tenderness on pressure of the orbital margins is a common sign in periostitis of the orbit, and frontal headache is often intense during the acute stages of inflammation in the orbital tissues, or of the frontal sinus.

(5) *Disturbance of vision* is often absent, but becomes a valuable sign when associated with changes in the fundus oculi, such as papillitis, pallor of the optic nerve, or retinal hemorrhages. Diplopia is also common.

Periostitis.—Periostitis of the orbit occurs in two forms, *acute* and *chronic*. The terms *circumscribed* and *diffuse* are applicable according to the supposed periosteal area involved in either variety.

Etiology.—Certain diathetic states predispose to this disease. They are—scrofula, syphilis, and rheumatism. Injuries and sudden changes of temperature are recognized exciting causes, but in many cases the exciting cause cannot be positively determined.

This disease attacks by preference the margin of the orbit (especially the outer margin), and extends more or less widely; suppuration (abscess) is prone to occur.

Symptoms.—The symptoms of an ordinary acute marginal periostitis

are—swelling, edema, and redness of the lids; chemosis of the conjunctiva, commencing at the equator of the globe; pain and tenderness on pressure at the part of the orbital margin affected. Sometimes a highly sensitive, tense spot may be discovered with the finger, or fluctuation if pus has formed.

Acute parietal (deep-seated) *orbital periostitis* is difficult to distinguish from cellulitis. The symptoms are violent and severe—intense headache, pyrexia, sometimes nausea, vomiting, and great prostration. The local symptoms are—swelling of the lids, chemosis, pain, increased when the eyeball is pressed backward, and more or less displacement and immobility of the eyeball.

Chronic orbital periostitis is far more frequent than the acute form, and is nearly always distinctly circumscribed. Its course is tedious, lasting for months or years. All the symptoms are less intense, though similar in other respects, except that the swelling of the lids is more a simple edema and the patient complains of a dull pain, usually worse at night. It commonly results in *abscess of the orbit*, occasionally in gradual resolution. Whenever pus has formed beneath the periosteum *caries* or *necroses* of the bone are liable to occur, and there is always danger of extension to the cranial cavity or septic infection, particularly when the disease is parietal. If the consecutive bone-disease involves the orbital margin, adhesion and retraction of the adjacent skin may cause eversion and distortion of the eyelids. This result is very common in children.

Prognosis.—This must be based chiefly on a recognition of the foregoing facts, and, in acute cases, on the immediate effects of treatment.

Treatment.—If the case is seen before pus has formed, leeches applied to the temple, cold compresses over the eyelids, and other antiphlogistic measures may arrest the inflammation. If pus is present or its formation seems to be inevitable, hot applications may be used, but incision should not be long delayed (see *Operations on the Orbit*); and in no case, acute or chronic, should an abscess-formation in the orbit be allowed to undergo spontaneous rupture. After an opening has been established suitable drainage and careful daily cleansing will be required so long as the discharge continues from the opening.

Appropriate remedies for the underlying constitutional cause must be administered in all cases. If syphilitic, the judicious use of mercury and iodid of potassium may be expected to give excellent results. In rheumatic or strumous cases constitutional treatment, although undoubtedly beneficial, is not so distinctly curative.

Caries and **necrosis** of the orbit are probably always preceded by periostitis, of which they are, therefore, common sequels.

Caries affects by preference the lower outer orbital margin, but may attack any part of the orbital walls, when deep-seated brain-complications are not unlikely to occur. It is seldom seen in adult life; often in children. A fistulous opening, surrounded by granulations, leads to an area of softened bone, which may be detected by careful use of a probe. Retraction of the skin and deformity of the lid, usually ectropion, ensues in most cases.

Necrosis is far less frequent than caries, and belongs to adult life. It is apt to follow denudation of a large area of bone from periostitis, or a fragment of bone detached by traumatism from the orbital margin may become necrosed (Fig. 324).

Treatment.—The fistulous opening and sinus should be gently cleansed two or three times daily with some antiseptic fluid. Mineral acids may be cautiously employed locally for the purpose of gradually dissolving the

diseased bone. Meddlesome surgery and the injudicious use of probes are harmful, and may induce orbital cellulitis or an extension of the disease. Removal of diseased bone may only be undertaken when near the surface or obviously completely detached; when the roof of the orbit is the part affected, the surgeon should be extremely careful in the use of instruments.

This disease is essentially chronic, and, besides the local treatment, appropriate constitutional remedies will be in order until a cure is effected.

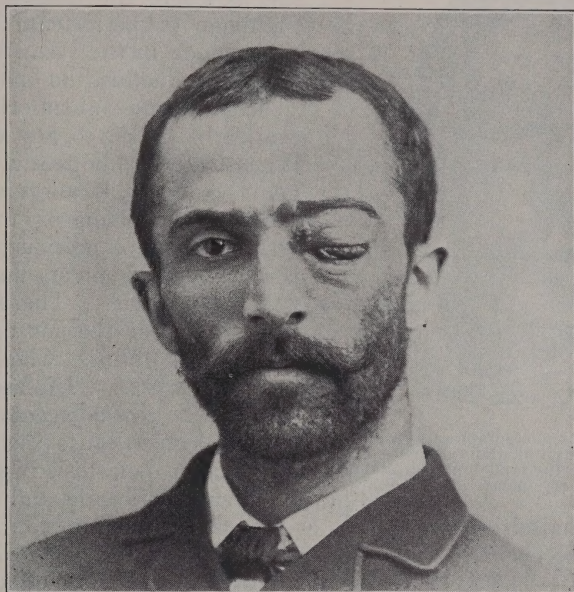


FIG. 324.—Syphilitic caries of the inner wall of the orbit.

The case represented in Fig. 324 recovered without a trace of deformity, after a course of mercurial inunctions followed by potassium iodid in large doses.

Cellulitis (*Phlegmon of the Orbit*).—This disease does not always present the same clinical picture. In all its forms the soft tissue surrounding the eyeball is inflamed, but the inflammation may be *acute*, *subacute*, or *chronic*, *monolateral* or *bilateral*. The inflammatory process may terminate in *resolution*, but commonly leads to *suppuration* and *abscess*.

In mild cases the symptoms are—moderate swelling of the lids, some exophthalmos, diplopia, dull pain, and little or no constitutional disturbance.

Acute phlegmonous orbital cellulitis comes on with chills, pyrexia, and deep-seated pain, aggravated by movements of the eyes. Intense headache is a common symptom. Loss of mobility of the eyeball may be complete. The lids become greatly swollen, red, and edematous; the conjunctiva is chemosed and hyperemic, suggesting a violent purulent conjunctivitis or a panophthalmitis; but the absence of profuse suppuration of the conjunctiva and the preservation of a normal red reflex from the pupil will prevent such an error of diagnosis (Fig. 325). Vision may be unaffected for some time, but it is not unusual for neuro-retinitis to appear, and this, in turn, may pass over into atrophy of the optic nerve and blindness. The pressure on the eyeball may cause dilatation of the pupil, anesthesia, or ulceration of the cornea, and, occasionally in bad cases, panophthalmitis.

In certain cases of an *erysipelatous type* extensive intra-ocular changes have

been observed, due probably to arrest of the circulation in the retinal blood-vessels, and consequent edematous exudation and hemorrhages in the retina.

Finally, an *abscess* forms, with characteristic fluctuation, usually below the inner portion of the supra-orbital ridge. Sometimes the inflammation leading to abscess-formation is of a more chronic character, and may not involve the entire orbital cellular tissue, as where the disease originates in the bone or periosteum in scrofulous subjects, or in the vicinity of a foreign body imbedded in the orbit.



FIG. 325.—From a photograph of a patient in the Philadelphia Hospital, under the care of Dr. de Schweinitz, suffering from double orbital cellulitis the result of erysipelas.

Etiology.—When orbital cellulitis cannot be traced to any definite cause, it is said to be idiopathic. Among the many recognized causes are—exposure to excessive changes of temperature, certain febrile conditions, such as scarlatina, typhoid fever, meningitis, and facial erysipelas. The last disease is responsible for the most violent types of orbital cellulitis, which is then apt to be bilateral. Diseased teeth and suppuration in adjacent cavities have been known to cause the affection. It occurs as a metastasis in pyemia and in puerperal septicemia, and in all cases of

acute panophthalmitis there is more or less diffuse inflammation of the tissues surrounding the eyeball.

Prognosis.—This is favorable in mild cases and those of a more chronic character, and recovery is likely to be perfect when the disease terminates in resolution.

Although purulent collections in the orbit usually tend toward the surface, there is always a liability to cerebral complications, which almost certainly terminate fatally. These are—meningitis, cerebral abscess, and the extension of phlebitis of the orbital veins to the cerebral sinuses. In this way the other orbit may become involved through the intervention of the cavernous sinus. In double cases of this nature a fatal issue is to be expected. If orbital cellulitis originates from pyemia or septicemia, the chances of recovery are of course exceedingly limited.

The danger to vision is to be estimated by the character and extent of the ocular complications already mentioned.

Treatment.—Absolute rest in bed is essential. In the early stage of acute inflammation cold compresses, leeches to the temple, aconite, and derivatives may be employed. If these measures are not effective in a short time, a change must be made to hot fomentations and general supporting treatment, or this plan must be adopted at the outset if there is evident depression of the vital forces.

If there is reason to believe that suppuration has taken place, no time is to be lost in making one or more incisions deep enough to reach the suspected pus. Incisions are best made with a Graefe knife, through the conjunctiva, the flat of the blade facing the eyeball. If pus is discovered, drainage must be maintained by means of rubber tubing or strips of iodoform gauze, and systematic cleansing of the cavity with antiseptic solutions will be necessary

until all suppuration has ceased. Ocular complications which threaten loss of vision demand operative interference even when there is no positive evidence of suppuration.

Inflammation of the Oculo-orbital Fascia (*Tenonitis*).—As a primary affection this disease is exceedingly rare, and is supposed to be an inflammatory, serous exudation into Tenon's capsule of rheumatic origin, but a few cases have been observed in connection with diphtheria and during attacks of influenza.

Its characteristic feature is a watery chemosis of the ocular conjunctiva, partial or complete, and out of proportion to other local manifestations of disease. There is, however, more or less edema of the eyelids, some loss of mobility of the eye, perhaps diplopia, exophthalmos, and a feeling of tension about the eye, and pain when its ordinary movements are attempted.

The treatment consists in hot fomentations and the administration of potassium iodid, salicylates, or the subcutaneous injection of pilocarpin.

A *secondary tenonitis*, with more solid exudation, is associated with any violent inflammation of the eyeball, and occasionally follows certain traumatism, such as squint-operations performed without antiseptic precautions.

Thrombosis of the cavernous sinus, as already stated, may result from phlebitis of the orbital veins during phlegmonous inflammation of the orbit, or it may be of intercranial origin, as in caries of the petrous portion of the temporal bone resulting from middle-ear disease, with infection of the superior petrosal and cavernous sinus.

A fetid discharge from the ear, with or without edema over the mastoid, and evidences of an orbital cellulitis and grave cerebral symptoms, are characteristic of this condition, which probably always terminates fatally.

Tumors of the Orbit.—The scope of this article admits only of a brief outline of this extensive subject, which, for convenience, may be arranged according to the following headings:

1. Tumors of the tissues of the orbit ;
2. Tumors arising from the periosteum or bony walls of the orbit (exostosis, etc.) ;
3. Tumors arising in the cavities or tissues close to the orbit ;
4. Pulsating exophthalmos.

New growths originating within the eyeball are not classified as orbital tumors, except when met with as local recurrences after removal of the eye.

The terms *primary*, *metastatic*, *congenital*, *malignant*, and *benign*, as applied to tumors of the orbit, have the same significance as in other departments of surgery, and are intended to convey an idea as to the nature of the growth.

All orbital tumors that have attained appreciable dimensions are likely to cause displacement of the eyeball. When confined within the funnel of the straight muscles the proptosis is in a forward direction ; displacement in any other direction will depend upon the size and position of the tumor according to the position or point of origin of the growth. Special symptoms in any case will depend upon the size, position, nature, and density of the growth. As the eyeball becomes pushed out of its natural position, the lids become distended and apparently enlarged ; occasionally, in high degrees of proptosis, they fail to close over the eyeball, and sometimes even recede beyond its equator.

Prognosis.—This depends on the nature, position and size, density, rate of growth, and possibility of successful surgical interference and its complete removal.



FIG. 326.—Fibroma of the optic nerve. The morbid growth in this case extended into the optic foramen, at which point chlorid-of-zinc paste was applied after removal of the eyeball and growth without exenteration. Ten years later there had been no recurrence.

Treatment.—In most cases treatment should consist in complete removal of the growth by operations conducted on general surgical principles. Cer-



FIG. 327.—Lymphangioma of the orbit.

tain growths originating in some vascular disease cannot be safely extirpated. Benign tumors may often be removed without sacrificing the eyeball, but

those of a distinctly malignant type call for complete exenteration of the orbit.

I. Tumors Originating in the Tissues of the Orbit.—Of these the *cystic formations* supply a large contingent. They are sebaceous, serous, blood and dermoid cysts, echinococci and cysticeri. Besides these there are

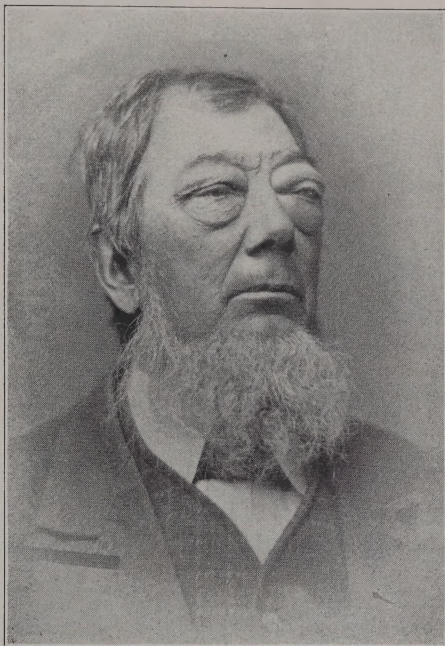


FIG. 328.—Lipoma of both orbits, stationary for many years. Patient died at an advanced age; orbital condition unchanged.

simple and cavernous angiomas, lymphangiomas (Fig. 327), lipomas (Fig. 328), enchondromas, lymphomas, and a variety of sarcomata which may take their origin from fibrous or connective tissue anywhere within the orbital cavity (Fig. 330).

Carcinoma as a primary tumor has been met with in connection with the lachrymal gland. Tumors originating in the lachrymal gland are, however, mostly of the adeno-sarcomatous type and non-malignant.

The *differential diagnosis* is not always an easy matter, but can generally be achieved by a careful study of all the signs and symptoms.

Treatment.—Cysts with fluid contents may be cured by simple incision followed by astringent or irritant injections.

Dermoid cysts should be thoroughly evacuated and the lining of the cavity destroyed with strong pigment of iodine or with nitrate of silver: excision of deep-seated cysts should never be attempted, since the cyst-walls can readily be destroyed by either of the drugs just named without damaging other structures. Many of the solid growths can be shelled out without much disturbance of the surrounding tissues.

Electrolysis has been found efficient in treating orbital angiomas. Some of them are sufficiently circumscribed to admit of removal by careful dissection.

II. Tumors which Arise from the Periosteum or Bony Walls of the Orbit.—These comprise the following:

- (1) *Sarcomata* or *fibro-sarcomata* occasionally spring from the periosteum.



FIG. 329.—Fibro-sarcoma of both orbits.

Figure 329 represents a case of the latter occurring in a boy of fourteen, in whom the entire periosteum of both orbits became involved. Some months

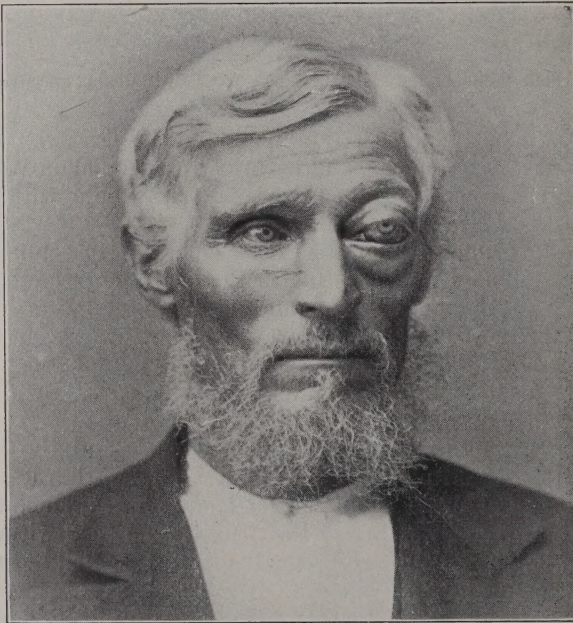


FIG. 330.—Sarcoma of the orbit originating in the tissues of the apex.

after removal of these growths death resulted from metastatic formations elsewhere.

(2) *Thickening of the periosteum* of an inflammatory nature sometimes

simulates a neoplasm, especially if localized and associated with hyperostosis of the underlying bone.

(3) *Exostoses* are a somewhat rare form of orbital tumor, characterized by slowness of growth, extreme hardness, and evident continuity with the adjacent bone. They may attain so large a size as to occasion great deformity. Most of these growths spring from the periosteum at or near the orbital margin or from neighboring cavities. They consist of an outer layer of ivory-like hardness and an inner more spongy structure. Some are of congenital origin, others may be traced to injury, or there may be no discoverable cause.

Treatment.—The only effective operation for exostoses is ablation by means of drill, hammer, and chisel. This operation is likely to be difficult and dangerous if the growth involves the roof of the orbit.

III. Tumors which Arise in the Cavities or Tissues close to the Orbit.—These are—

(1) *Encephalocele* or *meningocele* is an exceedingly rare form of tumor, containing cerebro-spinal fluid, with or without a hernial protrusion of brain-substance. It is of congenital origin, the result of defective ossification at some part of the orbital wall, by preference the anterior part of the fronto-ethmoidal suture, and appearing as a smooth, fluctuant, sometimes pulsating swelling, not adherent to the skin, and existing since birth at the upper inner angle of the orbit, is liable to be mistaken for a dermoid cyst.

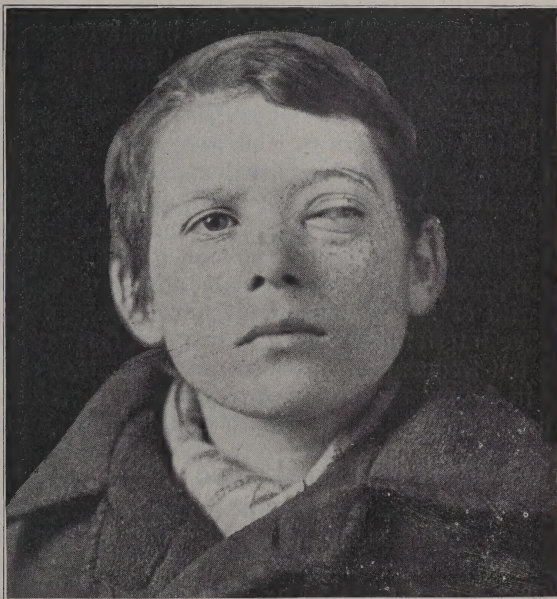


FIG. 331.—Ethmoidal mucocele.

Unlike the latter, it is not amenable to any form of operation or treatment. A correct diagnosis is therefore of paramount importance if an operation is contemplated.

(2) *Nevi*, *lupus*, and *epithelioma*, originating in the skin of the eyelids or face, may extend into the orbit.

(3) *Polypoid growths*, originating in the nasal cavities, sarcomatous, cancerous, or *osteoid growths* in the frontal, sphenoidal, or maxillary sinuses, *ethmoidal mucocele* (Fig. 331), or, even distention of these cavities by

fluid secretion, may, by invasion, simulate orbital tumors. An exact diagnosis may be difficult or impossible. The character of the proptosis, the condition of adjacent parts, and a careful consideration of all the signs and symptoms present will, however, usually reveal the true nature of the affection (see page 454¹).

Pulsating exophthalmos is a form of orbital tumor which results from some vascular disease within the orbital cavity, the primary lesion being commonly situated within the cranial cavity immediately behind the orbit.

Symptoms.—The ordinary signs of pulsating exophthalmos are—protrusion of the eyeball (occasionally both), and pulsation, which may sometimes be both seen and felt. The stethoscope reveals a distinct *bruit* when placed upon the brow or closed eyelid. There are swelling and a passive hyperemia of the latter and of the subconjunctiva, sometimes presenting an appearance not unlike that of orbital cellulitis. The retinal veins are usually distended and tortuous, and there may be retinal hemorrhages, optic neuritis, and more or less impairment of vision. The protrusion, fulness of the vessels, and pulsation are increased by stooping the head.

The subjective symptoms are pulsating tinnitus or noises in the head, and pain, likewise increased by stooping, and diminished by compression of the carotid artery.

This assemblage of symptoms is nearly always due to the formation of *aneurysmal varix* in the cavernous sinus, the internal carotid thus directly pumping blood into the orbital veins. The initial lesion is in most cases caused by traumatism, such as falls or severe blows upon the head or face; not very rarely, however, especially in women, the arterio-venous communication (rupture of the carotid in the sinus) has occurred spontaneously.

Some other lesions, so rare as to constitute pathological curiosities, have been known to cause pulsating exophthalmos: they are—aneurysm of the ophthalmic artery within or behind the orbit, or of the carotid in the sinus, pulsating angioma, and medullary osteo-sarcoma of the orbital walls.

Treatment.—Spontaneous cure is possible: so long, therefore, as there are no urgent symptoms, such as severe pain, attacks of epistaxis, or impairment of vision, with extensive or increasing intra-ocular changes, there is no necessity for active interference. Rest in bed, full doses of potassium iodid, and intermittent but frequent compression of the common carotid may arrest the disease; but in the presence of urgent symptoms ligation of the common carotid should not be delayed. The results of this operation have been satisfactory in a large percentage of cases so treated.

Exophthalmic Goiter (*Basedow's Disease, Graves's Disease, Cardiac Exophthalmos*).—This disease comes rather more appropriately within the domain of general medicine, since the ocular symptoms are but a local manifestation of a more serious general disturbance or form of debility, which is associated not only with exophthalmos, but also with enlargement of the thyroid gland and increased action of the heart (*tachycardia*). Any one of this trio of symptoms may be in abeyance or may predominate over the other two. For this reason there is a lack of uniformity in the signs which indicate the presence of this disease.

Symptoms.—With regard to the ocular symptoms, the exophthalmos, almost always bilateral, is much greater in some cases than in others, is subject to a certain amount of spontaneous variability, and may, in the early stages at least, be temporarily diminished by pressure. The eyeballs are pushed

¹ For a detailed description of this class of tumors the reader is referred to an article by Chas. S. Bull in the *New York Medical Journal* for Dec. 19, 1891.

straight forward; their mobility is not impaired. In extreme cases the lids may not sufficiently cover them to secure adequate protection, and damage to the cornea may ensue.

Vision is unimpaired, and intra-ocular changes have not been observed, except occasionally visible pulsation of the central artery of the retina, and sometimes the retinal arteries appear relatively larger than they should be as compared with the veins.

The exophthalmos, even when slight, is characterized by a peculiar staring appearance of the eyes, giving the patient an astonished or frightened look. This is due to a retraction of the organic levator of the lid. The resulting widening of the palpebral fissure is known as *Dalrymple's sign*.

On looking downward the upper lids do not perfectly follow the movements of the eyeballs, as in health; consequently the sclera above the corneal margin becomes visible (*v. Graefe's sign*). This symptom is not always present, and it may exist without exophthalmos in the early stage, or be persistent after the latter has disappeared if a cure has been effected. Diminished or imperfect winking movements of the lids are often noticeable (*Stellwag's sign*). These, together with the widened palpebral fissure, may induce a tendency to desiccation of the cornea, and probably account for the sense of heat and discomfort in the eyes of which these patients often complain.

The enlargement of the thyroid body, primarily due to enlargement of its blood-vessels, may be slight or very considerable. As a rule, it is evenly distributed, but there are some marked exceptions to this rule; in these the right side is apt to be the larger. The enlarged thyroid feels soft and elastic in most, but not in all, cases. The chief point of distinction between exophthalmic and other forms of goiter is that in the former the hand detects a whirring sensation and strong pulsatory movement with each cardiac impulse. These circulatory phenomena are associated, as might be expected, with a loud rasping *bruit*.

The carotids are probably distended and pulsate strongly. This pulsation is visible, as well as audible, along the course of these arteries, and the patient often complains of a beating sensation communicated to the head. Signs of engorgement of the large cervical veins are also often present. Pulsatory phenomena sometimes also exist in the thorax and abdomen. The action of the heart is increased both in frequency and intensity; the pulse, never less than 100, becomes considerably accelerated by the slightest exertion or mental excitement.

Some enlargement of the heart, especially of the left ventricle, is not uncommon, and variable cardiac murmurs may be present; but if recovery takes place, these signs disappear: they are therefore assumed to be of a functional character.

Persons suffering from Basedow's disease are often irritable and excitable; most of them are anemic, some chlorotic; a tendency to emaciation even when the appetite and digestion are unimpaired has often been observed.

Etiology.—This disease belongs almost exclusively to adult life, and in women rarely develops after the menopause. The male sex is comparatively exempt from it. As recognized exciting causes may be mentioned diseases of the genital organs, worry, mental excitement, anxiety, and fright.

Although exophthalmic goiter has been known to come on suddenly, this is the exception; as a rule, the onset is gradual—first palpitation, later enlargement of the thyroid, still later exophthalmos; often months or years elapse before the disease is fully developed. Innumerable functional nervous

disturbances, often of an hysterical type, come and go during the course of the disease. After a long period of sameness a gradual improvement may take place, ending in recovery, or there may be indefinitely repeated periods of improvement, and relapse or gradual exhaustion, with intercurrent complications, may end in death.

Prognosis.—The prognosis is said to be least favorable when the disease attacks elderly persons of the male sex. As far as vision is concerned, the source of danger has already been alluded to. An excessive exophthalmos, with imperfect closure of the lids, may lead to *keratitis e lagophthamo*, and the resultant corneal opacity or ulceration may lead to partial or complete blindness of one or both eyes (see also page 317).

In the absence of definite and constant pathological lesions discoverable after death, we are, for the present, constrained to class exophthalmic goiter as a functional disease which seems to depend upon a disturbance of innervation, especially that of the sympathetic. The present tendency is to regard certain parts of the central nervous system (medulla and upper part of the spinal cord) as the primary seat of this strange disease.

Treatment.—For the general treatment the reader will find this part of the subject elaborately discussed in most of the standard works on general medicine and neurology. The ophthalmic surgeon may, however, be called upon to deal with corneal complications. Undue exposure of the cornea may be obviated by an operation for narrowing the palpebral fissure (tarsorrhaphy, see page 547). Slight degrees of corneal irritation may be relieved by the use of a carefully adjusted compressive bandage and by soothing applications, such as vaselin, or mucilaginous collyria containing a small quantity of sodium bichlorate or boric acid. Refractive error should always be corrected.

INJURIES OF THE ORBIT.

Injuries may be limited to the soft parts or involve the bony walls as well. The danger of such injuries depends upon their nature and extent. It is often impossible to estimate either of these factors exactly, except in the light of subsequent events.

With injury of the soft parts there may be more or less damage to the lids and eyeball. The appearance of orbital fat in the wound is proof positive that the orbit has been penetrated. Extravasation of blood with ecchymoses of the conjunctiva and integument, and exophthalmos, are commonly present. Paralysis of ocular muscles and loss of vision from damage to the optic nerve are significant. Foreign bodies of considerable size remaining in the orbit may displace, or even completely luxate, the eyeball.

Foreign bodies thrust into the orbit may be difficult to discover, and when aseptic have been known to remain for an indefinite period without creating serious reaction. Small foreign bodies—*e. g.* shot-grains—not readily discoverable by ordinary examination, may be located by means of the *x*-rays (see Appendix, page 607). Pointed or blunt objects withdrawn after penetration not infrequently have pierced the cranial cavity, the gravity of the lesion only being discoverable when cerebral complications occur.

Injuries to the bones of the orbital margins are a common result of crushing blows upon this part. The diagnosis is not difficult if the injured bone is sufficiently displaced to cause distinct unevenness or if a portion of the margin is detached. Mere sensitiveness to pressure is not diagnostic of fracture, though always coincident with it. The marginal fracture may extend as a fissure to any part of the orbit, even to the optic

foramen; in the latter case blindness may result from laceration of the optic nerve or hemorrhage into its sheath, or fissure of the orbital walls may occur from fractures of the base of the skull.

Emphysema of the lids and orbital tissues is quite common even where the violence has not been great, and indicates fissure of the thin walls between the nasal or ethmoidal cavities and the orbit: a suddenly developed elastic and crepitant swelling is quite characteristic of this. Exophthalmos due to this condition can be reduced by pressure with the finger. If due to extravasation of blood, as it often is in orbital fractures, the swelling cannot be reduced in this way.

Injuries of the orbit may recover perfectly after absorption of extravasated blood or air, but lesions of the eyeball, the optic or the third nerve, or the ocular muscles, often cause permanent impairment of function; or phlegmon of the orbit, with its attendant danger, may set in; or the contents of the cranial cavity may be involved directly or become so in consequence of the extension of septic inflammation following the injury. A fatal issue is then to be expected.

Treatment.—In recent injuries of the orbit, if there be an open wound it must be carefully and thoroughly cleansed and disinfected. Exploration for suspected foreign bodies is a matter which can only be left to the judgment and skill of the surgeon. Exploration with the finger, when practicable, is always to be preferred. Small and probably aseptic foreign bodies should on no account be searched for. Suitable provision for drainage of the wound may be required, and an antiseptic dressing is to be applied. Should suppuration ensue, the treatment will be that of orbital cellulitis. Rest in bed is essential if the injury is still severe.

Hemorrhage into the orbit when at all abundant causes an immediate exophthalmos, later ecchymoses of lids and conjunctiva; this latter may be the only sign of atrophic hemorrhages. It is a common result of severe injuries of the orbit, often occurs with fracture of the skull implicating the orbital roof, occasionally without this lesion.

Spontaneous orbital hemorrhages have occasionally been seen in scorbutus, hemophilia, and during violent paroxysms of coughing. A copious bleeding into Tenon's capsule is an accident, fortunately rare, in operation for squint.

Injury of the Optic Nerve.—Laceration of the optic nerve may occur, as has been stated, in connection with fracture of the bony walls of the orbit. But, independently of such an association, the optic nerve may be injured by a sharp stick, as in a case reported by Noyes, by a knife-thrust, or by a bullet. Atrophy of the nerve and blindness are the results of such accidents, which are not frequent, twenty-one cases having been collected by Aschman in 1884. Laceration of the nerve and the central retinal blood-vessels may be followed by retinitis proliferans, as in the case recorded by C. Zimmermann.

Dislocation or luxation of the eyeball exists when the eyeball has been pushed so far forward that the lids remain contracted behind it.

Traumatisms, such as when a large foreign body has been driven into the orbit from the outside, the use of an assailant's thumbs in certain brutal assaults—the so-called gouging—and a similar self-mutilation by insane persons, have been known to cause this condition, which would probably be less rare if the eyeball did not usually rupture at the time of injury. Traumatic dislocation is apt to cause blindness from rupture or laceration of the optic nerve.

The luxations that readily occur during the continuance of any morbid

condition attended with excessive exophthalmos are a mere complication of a more serious condition.

Treatment.—The eyeball should be replaced as soon as possible. To effect this division of the outer canthus may be necessary. After reposition a compressive bandage may be required, and in the second class of cases *tarsorrhaphy* (page 547) may be done to prevent recurrence.

Enophthalmos (*Idiopathic and Traumatic*).—A condition in which the appearance of the eye is the opposite of exophthalmos, the eyeball being retracted, is met with under various circumstances, as in wasting diseases with extreme emaciation and absorption of orbital fat; in Asiatic cholera because the enormous waste of fluids causes shrinkage of the orbital as well as other tissues; as one of the symptoms of paralysis of the cervical sympathetic; in neurotic anesthesia of the face, as in lepra anæsthetica; and, finally, in a form distinctly traumatic in its origin.

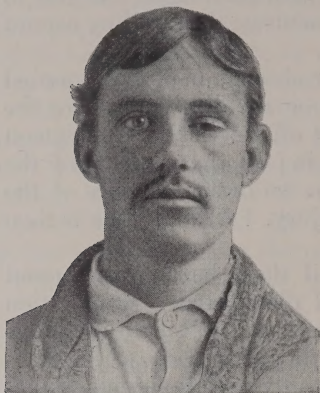


FIG. 332.—Traumatic enophthalmos, patient looking straight forward; sunken appearance, resembling a badly-fitting artificial eye, well shown (de Schweinitz).

In some cases immediately—in others weeks or months—after traumatism, such as a blow upon the upper margin of the orbit without direct injury to the eye, enophthalmos appears, and may be due to paralysis of (Müller's) retractor of the lids—*i. e.* a local lesion of the sympathetic—or to trophic disturbance with atrophy of the orbital tissues. It has also been

ascribed to fracture with depression of the orbital floor, and to cicatricial contraction of the orbital tissues following certain injuries (Fig. 332).

OPERATIONS.

PREPARATION OF REGION OF OPERATION, INSTRUMENTS, AND DRESSINGS; ANESTHESIA; LOCAL HEMOSTASIS.

BY G. E. DE SCHWEINITZ, A. M. M. D.,
OF PHILADELPHIA.

ALL the principles of clean surgery and the main practices of aseptic surgery are necessary in all ophthalmic operations.

1. **Preparation of the Hands of the Operator.**—Scrub the hands thoroughly with soap and warm water; then clean the spaces beneath and around the nails; soak the hands in 95 per cent. alcohol for not less than one minute; on removing them place them without drying in a solution of 1 : 1000 corrosive sublimate, and allow them to remain there for at least one minute.

2. **General Preparation of the Patient.**—Necessarily, each patient preceding an operation should be placed in the best possible physical and mental condition. Usually a laxative is advisable. The author is accustomed to give calomel on the night preceding the operation and a saline in the morning.

The nares of patients requiring corneal section should be sprayed either with a mixture of listerin and Dobell's solution or with equal parts of water and the peroxid of hydrogen, which flushes out the passages and probably, largely by mechanical effect, gets rid of infectious material. Independently of the fact that chronic bronchitis by virtue of the cough which it produces is a complicating circumstance, it is perfectly possible that pathogenic germs may migrate from the lower respiratory tract and destroy the effects of an operation. Under these circumstances it has been advised to administer capsules of oil of eucalyptus, which is a good stimulating expectorant and plays the part of a mild antiseptic. It is almost needless to point out the necessity of ridding the patient of any inflammation of the conjunctiva, margins of the lids, or lachrymal passages preceding operative interference on the ocular tissues. If there is dacryocystitis, the usual treatment of this affection is indicated (page 268). Haab has recommended sealing the lachrymal puncta with a galvano-cautery needle. The inner corner of the eye may be covered with sterile iodoform powder to prevent access of infected fluid from the lachrymal passages to a corneal incision.

3. **Preparation of the Skin of the Region of Operation.**—The skin should be treated first with soap and water, then with alcohol, and finally with corrosive sublimate, 1 : 2000. These irritating substances must not enter the conjunctival sac, but the face, surface of the closed lids, eyebrows, brow, and scalp should be thus prepared. The ciliary margins should be cleansed with soap and water followed by bichlorid of mercury, 1 : 5000. The parts should be kept covered with a compress of lint soaked in a bichlorid solution

1 : 5000, which should remain in place for at least one hour before the operation begins.¹

4. Preparation of the Conjunctival Cul-de-sac and the Ciliary Margin.—The method to be employed depends upon the nature of the operation. In enucleation, for example, the ordinary rules of antiseptic surgery are applicable, and the same is true, for instance, in an advancement, save only that the strength of the bichlorid solution commonly employed by general surgeons must be decreased. A solution of a grain to the pint is quite sufficient. Numerous investigations have demonstrated that it is impossible to sterilize the conjunctival sac. Therefore the object is to reduce the vitality of the microbes that cannot be washed away, and the mechanical effect of the fluid used is quite as potent as any germicidal value which it may exercise. Strong germicidal solutions are likely to be deleterious to the delicate epithelium of the corneal tissue. For irrigating purposes the surgeon may employ, provided the fluid reaches all portions of the conjunctival cul-de-sac and thoroughly scours out the folds of the conjunctiva, boric acid, 4 per cent., or physiological salt solution, which may be prepared by adding a heaping teaspoonful of salt to a pint of sterilized water, bichlorid of mercury, 1 : 10,000, or any of the other antiseptics mentioned in the footnote. The author prefers either the physiological salt solution or the solution of boric acid. As a final precaution the lids should be turned and gently mopped with a pledget of cotton soaked in the antiseptic solution, especial care being particularly taken to cleanse the region of the inner canthus.

The experiments of Bernheim, Stroschein, and many others have demonstrated the impossibility of completely sterilizing the ciliary margin; hence careful cleansing with soap and water, followed by the salt solution or one of the antiseptics mentioned, accomplishes the only practical result—namely, diminution of the vitality and number of the cocci. All of these preparations should be made immediately preceding the operation (see also page 575).

5. Preparation of the Instruments.—All coarse instruments, such as hooks, scissors, etc., should be cleansed first with soap and water, then boiled, and finally placed in an antiseptic bath, where they remain until required, and they should be covered with this fluid for not less than twenty minutes before the operation. The antiseptic bath may be carbolic acid, 1 : 20, or absolute alcohol, preferably the latter. Immediately preceding the operation the instruments may be removed from the antiseptic bath and placed in a dish of sterile water. Sharp instruments—cataract-knives, keratomes, cystotomes, etc.—must be cleansed with great caution, lest damage be done to their edges. First, the edge of the instrument is inspected with a magnifying-glass; then the instrument, wrapped in cotton, is put in the boiling water, and from this transferred to a dish containing absolute alcohol. When the operator is ready the knife is removed from this fluid and the blade freed from alcohol by dipping it momentarily in a vessel containing boiling water. Stroschein and others believe that antisepsis is secured if the blade is rubbed with cotton wool soaked in a mixture of equal parts of absolute alcohol and ether, to which a few drops of ammoniac have been added. Subsequently the knife may be washed in a 5 per cent. solution of carbolic acid. Instead of placing the instruments in absolute alcohol or carbolic acid, it is the practice of some surgeons to put them in a physi-

¹ In place of sublimate solution the following antiseptics have been recommended, especially in ophthalmic work: aqua chlorinata; trichlorid of iodine, 1 : 2000; cyanuret of mercury, 1 : 1500; oxycyanid of mercury, 1 : 1000; and especially formaldehyd, 1 : 2000. Of this list the cyanuret of mercury and formaldehyd have most to commend them, the latter substance being a most efficient ocular antiseptic, and the author has been most favorably impressed with its value.

ological salt solution or in sterile water; or they may be used directly after removal from the boiling water. Perfect sterilization of non-cutting instruments made of platinum may be secured by bringing them to a white heat in the flame of a lamp just before the operation (Grüening).

Dr. E. A. de Schweinitz recommends sterilization of instruments with the vapor of formaldehyd. The practical value of formaldehyd in the disinfection of small instruments has also been demonstrated by H. O. Reik and W. J. Watson,² who have designed a special sterilizing apparatus.

6. Dressings.—These must be modified according to circumstances. In plastic operations about the lids the ordinary antiseptic dressing is usually applied—protective and antiseptic gauze covered by a wet or dry bichlorid roller. Iodoform is also used under these circumstances, although some surgeons—for example, Noyes—do not consider it an advantage. Dressings impregnated with antiseptic substances bought ready made from the various shops are not satisfactory. Sterilization with steam is the proper method. If a wet dressing is desired, the fabric may be soaked in one of the antiseptic fluids, usually bichlorid, 1:5000, or in a physiological salt solution which has been sterilized by boiling. Bits of gauze prepared by sterilization with steam are much more desirable than cotton for removing blood, etc. from the area of operation. If the lighter forms of cataract dressing are employed, such as isinglass plaster or small wads of cotton held in place by strips of surgeon's isinglass plaster, these should be properly disinfected before application.

When the eye is bandaged, either the single (Fig. 333) or the double



FIG. 333.—Figure-of-eight of one eye.

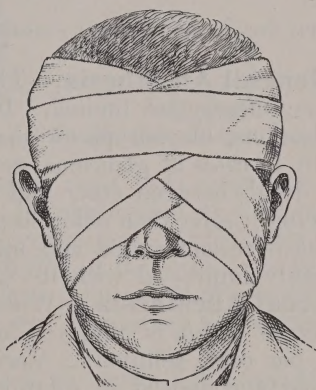


FIG. 334.—Figure-of-eight of both eyes.

bandage (Fig. 334) is employed, or a modification of Liebreich's bandage (Fig. 335). In most cases a dry, absorbent material—for example, gauze sterilized by heat, is most useful, although there is no objection to a flannel roller, if it is desired, when this is placed over a properly applied antiseptic pad. The dressings applicable to the different operations vary according to the desire of the surgeon. Cataract dressing is described on page 581. In addition to the dressing recommended there, Ring's ocular mask (Fig. 336), which covers the bandage, and which may be understood by a reference to the figure, is of great advantage.

Sutures.—These may be of catgut or silk. The latter is usually black, ordinarily known as iron-dyed, although for delicate sutures in the conjunctiva the white silk—such, for example, as comes in Stevens's tenotomy case—is of great advantage. These sutures should be soaked in an antiseptic bath preparatory to their use.

Catgut specially prepared by the instrument-maker may be purchased, but it is better for the surgeon to prepare this for himself. The author is accustomed to use a delicate sulpho-chromic surgical gut, which is kept in a solution of bichlorid of mercury in alcohol, 1 : 1000. If sponges are used in plastic operations or in enucleations, they should be properly disinfected by the ordinary processes. Generally, the area of operation may be kept clean by gently touching it with cotton soaked in bichlorid solution, or by gauze which has been sterilized by heat.

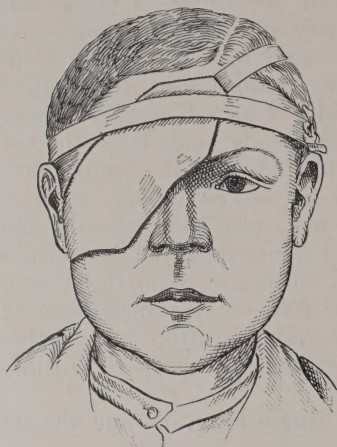


FIG. 335.—Modified Liebreich's bandage.

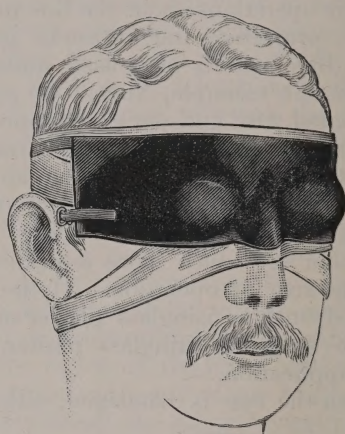


FIG. 336.—Ring's ocular mask.

General Anesthesia.—The indications for general anesthesia in ophthalmic surgery are limited. In children or in very nervous adults, and for enucleations, blepharoplastic operations, occasionally in advancements, and usually in cases of glaucoma, general anesthesia is necessary. The surgeon must decide between ether and chloroform. The author prefers the former, believing it safer than chloroform or the A. C. E. mixture. Bromid of ethyl has been recommended and much employed, but the author has not been favorably impressed with its value.

Local Anesthesia.—When local anesthesia is required, usually *hydrochlorate of cocain* is employed in 2 or 4 per cent. solution (some surgeons use a 10 per cent. solution). Various fungi grow readily in solutions of this alkaloid, and, indeed, in solutions of any of the alkaloids commonly used in ophthalmic practice. A number of methods of sterilization are employed—namely, sterilization by heat, by the addition of an antiseptic (1 : 5000 solution of bichlorid of mercury, 4 per cent. of boric acid, formaldehyd, as recommended by Valude, or trikresol, 1 : 1000, as recommended by E. A. de Schweinitz of Washington), or by a combination of these two methods. The most satisfactory procedure is to boil the solution. A number of convenient flasks for this purpose are in the market, among the best being those introduced by Stroschein of Wurzburg (Fig. 337), and the one devised by Llewellyn of Philadelphia (Fig. 338). The Stroschein flask may be understood by a reference to the figure. The solution is placed in the Llewellyn flask and boiled. After the liquid is cool and ready for use the warmth of the hand causes the fluid to drop from the end of the pipette. If it is desired to preserve the solution after boiling, a portion of one of the antiseptic substances previously mentioned may be added.

In order to avoid the drying and roughening of the corneal epithelium caused by cocain the lids should be kept closed after each instillation. The drug should not be used too freely or it may, according to Mellinger, prevent closure of the corneal wound. Three instillations of a 4 per cent. solution, five minutes apart, are sufficient for a corneal section. Gelatin disks impregnated with cocain, as recommended by some surgeons, have no advantage over the solution, and general anesthesia is preferable to strong solutions of cocain, which have been recommended in the operation of curetting lupus and similar growths.

In addition to cocain, a number of other substances (for example, *tropacocain*) have from time to time been recommended as local ocular anesthetics, but without establishing claims to special favor. Five may be briefly described :

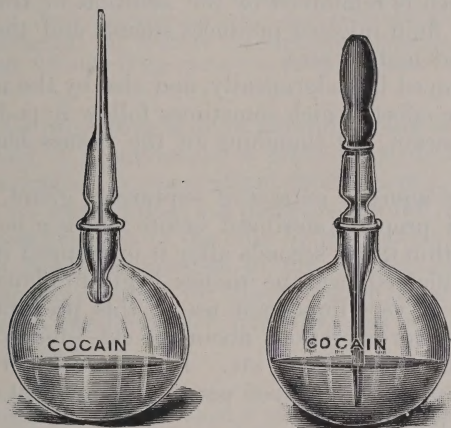


FIG. 337.—Stroschein's flasks.

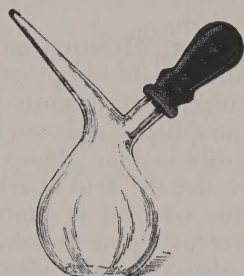


FIG. 338.—Flask for sterilizing collyria.

(1) *Hydrochlorate of eucain "A,"* like cocain, is a local anesthetic, and may be employed in 2 per cent. solution. Its application is followed by very considerable smarting and conjunctival congestion. It has little or no effect upon the pupil, and is said not to cause drying of the corneal epithelium. The anesthesia begins in a few minutes and lasts from ten to fifteen minutes. The author has been unable to see in what way it possesses any advantages over cocain.

(2) *Hydrochlorate of eucain "B,"* is related to eucain "A," and also to cocain and tropacocain. It is not decomposed by boiling, and is less irritating than the older eucain, according to Silex. A 2 per cent. solution causes local anesthesia in from one to three minutes, which lasts about fifteen minutes. It does not dilate the pupil, apparently does not decrease intra-ocular tension nor cause clouding of the corneal epithelium.

(3) *Holocaïn* (*p-diäthoxyäthenyl diphenylamidin*), introduced into ophthalmic therapeutics by Hirschberg and Gutmann, and originally known as "amidin," is an active local anesthetic closely allied in its general properties to phenacetin. A 1 per cent. solution causes anesthesia in from fifteen seconds to one minute, which lasts for ten minutes, preceded by a moderate burning sensation. Hasket Derby considers it advantageous because it does not enlarge the pupil, does not affect the accommodation, does not increase intra-ocular tension, and is itself bactericidal. *Holocaïn* is highly recommended by H. V. Würdemann.

(4) *Acocin*, related to caffein and theobromin, in a solution of 1 : 100 pro-

duces anesthesia in an unirritated eye. It has no effect upon accommodation or the size of the pupil, and does not increase intra-ocular tension. It is not as satisfactory, however, as cocain or holocain.

(5) *Dionin*, especially advocated by Darier, is a remarkable local anesthetic. A 5 or 10 per cent. solution when dropped into the eye produces first smarting, then a distinct chemosis of the conjunctiva, followed by anesthesia and analgesia. The anesthetic effect lasts for hours. It has been especially advocated to relieve the pain of iritis, keratitis, and glaucoma.

Infiltration-anesthesia.—In lid-operations cocain solution, 2–4 per cent., is sometimes injected beneath the skin, but a more efficacious and safer procedure is the so-called infiltration-anesthesia introduced by C. L. Schleich. This consists of an intracutaneous (not subcutaneous) injection with a hypodermic syringe or with one specially devised for the purpose, of a $\frac{1}{5}$ per cent. solution of sodium chlorid, which is reinforced by the addition of from $\frac{1}{100}$ to $\frac{1}{50}$ per cent. of cocain. The fluid injected produces edema, and the anesthesia is strictly limited to the edematous area.

Eucain has been much employed hypodermically, and also by the infiltration method. The general toxic effects which sometimes follow hypodermics of cocain do not appear with eucain, but sloughing of the tissues has been reported.

Local Hemostasis.—The aqueous extract of suprarenal gland, which should be freshly prepared and properly sterilized before use, is a powerful astringent and hemostatic. Within thirty seconds after it is dropped into the conjunctival cul-de-sac of an inflamed eye, the tissues begin to blanch, and speedily become almost white. A very important use of this preparation is to render the field bloodless in minor operations about the eye—for example, in the removal of pterygia, squint operations, etc. It is probable that its power to lessen the congestion of inflamed eyes permits subsequent cocain anesthesia to take place more readily.

Other preparations of suprarenal gland on the market which are equally valuable are *atrabilin*, especially advocated by Wolffberg in Breslau, and *adrenalin*, a principle isolated from the gland by J. Takamine, which is a crystal formation. It may be used in solution in the form of *adrenal chlorid*. It blanches the conjunctiva in a solution of 1 : 10,000, but may be employed in a strength of 1 : 1000.

OPERATIONS UPON THE EYELIDS.

By F. C. HOTZ, M. D.,

OF CHICAGO.

THE operations upon the eyelids may be divided into two groups. The *first group* embraces a number of surgical procedures which every practitioner having a general training in surgery may easily employ. The *second group* embraces those operations requiring a degree of dexterity and judgment which can be acquired only by special training.

MINOR OPERATIONS.

1. **The Removal of Eyelashes.**—The simplest procedure for removing eyelashes is (a) epilation by means of a *cilium-forceps*.

With the fingers of the left hand a gentle steady pressure is made upon the lid, and with the forceps, held in the right hand, the eyelash is seized as near as possible to the

skin and drawn out with a steady traction. Jerking must be avoided, lest the hair-shaft break off; also not more than one eyelash must be grasped at one time, because extraction of several eyelashes together is very painful.

Eyelashes so removed usually grow again; epilation, therefore, is the proper procedure only where a temporary removal of cilia is indicated. If a permanent removal is desired, we must have recourse to electrolysis or the scalping operation.

(b) Electrolytic removal of cilia requires a mild galvanic current and an electrolytic needle set in a convenient handle.

The eyelid being well steadied in the manner described above, the point of the needle connected with the negative pole of the battery is inserted along the shaft of the eyelash until it reaches the root, about 3 mm. under the surface. The other electrode, represented by a moist sponge, is placed upon the temple or the hand of the patient; this closes the circuit, and at once a whitish froth makes its appearance around the needle. After a few seconds the needle is withdrawn, the eyelash seized with forceps, and extracted. If it offers the slightest resistance, the electrolytic needle should be re-inserted, for only if the eyelash is perfectly loose are we sure of the complete destruction of its root.

This procedure is quite painful; hence if a great number of cilia are to be removed, it is advisable to treat three or four eyelashes only at one sitting and to repeat the operation at intervals of a few days. As the operation produces no scars, it does not disfigure the lid. In this respect it is far preferable to the extirpation of the cilia by the scalping operation.

(c) *Scalping* consists in the excision of the whole ciliary border. The instruments required for this operation are a fine scalpel, forceps, small curved needles, a needle-holder, fine silk, and a lid-plate made usually of shell or hard rubber.

The surgeon, putting the thumb of his left hand upon the lid supported by a plate, makes a slight pressure upon it to turn the lid-border into full view. With the scalpel in his right hand he then makes an incision all along the lid-border just behind the eyelashes (Fig. 339), and deepens this incision by repeated strokes of the scalpel until the

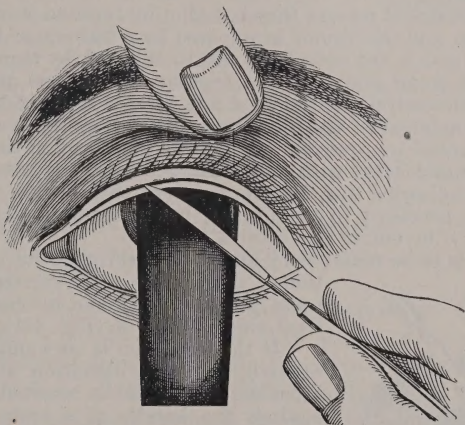


FIG. 339.—Making the intermarginal incision.

bulbs of the cilia are exposed as small black dots in the anterior margin of the wound. This incision is known as the *intermarginal incision*. Its correct execution requires a steady hand and watchful eye, for it is essential that no hair-bulbs shall remain behind in the posterior margin of the incision.

The next step consists of a transverse incision through the skin, made just behind the eyelashes; at both ends this incision is continued into the intermarginal incision, the two incisions thus including a long and narrow strip containing all eyelashes. This

strip is seized with fine forceps, and dissected up by deepening the cutaneous wound until it meets the intermarginal incision behind the hair-bulbs. After a careful inspection has convinced the operator that no hair-bulbs are left behind, the wound is thoroughly cleansed and closed by fine silk sutures, which are removed after three days.

In former years scalping was frequently performed, but since the introduction of electrolysis and improved modern operations for entropion it is seldom required, and fortunately for the patients, as it produces a very hideous and permanent disfigurement of the eyelid.

Abscesses of the lid are opened by a *transverse* incision through the skin and treated according to the general principles of surgery.

Hordeolum (or styne) is opened by a small incision and its contents are expelled by gentle pressure.

2. Removal of a chalazion (tarsal tumor, Meibomian cyst) can, in the majority of cases, be performed by an incision through the conjunctiva; but if it is very large, causing a decided protuberance of the skin, it is more

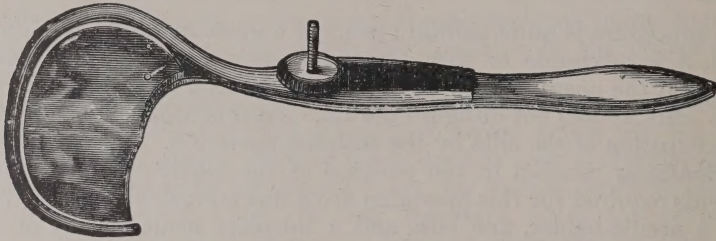


FIG. 340.—Knapp's lid-clamp.

convenient to attack the tumor through the external integument. In either case the use of the lid-clamp (Fig. 340) is very advantageous, as it makes the operation practically bloodless.

If the surgeon decides to remove the chalazion by incision through the skin, the lid is secured in a clamp and the tumor is exposed by a transverse incision through skin and muscular layer, and is cut open from within outward by transfixing its base with the narrow blade of a small scalpel. The contents of the cyst are removed, and each half of its wall is successively seized by a fine forceps and excised by small curved scissors. Upon the removal of the lid-clamp there is a free oozing of blood, which, however, is easily checked by pressing a compress gently upon the lid; next the lid is cleansed and the wound covered with iodoform; a bandage is not necessary. As these transverse incisions, following the natural creases of the lid-skin, have no tendency to gape, it is not strictly necessary to use sutures; but if the wound is very large, it is perfectly proper to close it by one or two sutures.

If the chalazion is to be removed by an incision through the conjunctiva, the position of the lid-clamp is reversed, its plate being put upon the outer side and its ring upon the conjunctival side of the lid (Fig. 341).

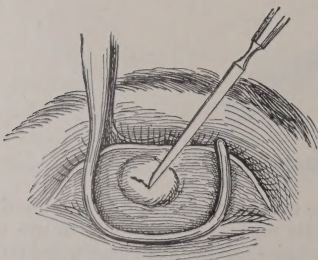


FIG. 341.—Incision of chalazion.

If the chalazion is very small, the clamp may be omitted, and the operation still be made almost bloodless if the lid is everted and firmly pressed against the handle of a scalpel or the nail of an assistant's finger.

The clamp being screwed down the lid is everted; the cyst, marked by a dark red, prominent patch in the conjunctiva, is opened by an incision; a small curet is introduced and the contents are scraped out. Overhanging edges of the cartilage may be trimmed off without fear of producing a contraction and malformation of the tarsus. The cartilaginous walls of the chalazion often contain small pockets filled by the same granulation-tissue; these side-pockets should always be

searched for and thoroughly scraped out, for if overlooked they form the nucleus of a new tumor, and often account for the recurrence of the chalazion at the site of the operation.

When the clamp is removed the cyst-cavity fills with blood, producing more or less tumefaction of the lid; but in a few days the blood is absorbed and the lid-swelling is gone. No special dressing is needed, except perhaps the application of a warm wet compress for a few hours to allay pain.

Dr. Agnew's method of removing the contents of the chalazion through an intermarginal incision has no material advantage over the other methods.

To remove chalky deposits in the Meibomian glands, the lid is everted and the conjunctiva over the white deposit is punctured, and the chalky grain picked up on the point of a Graefe cataract-knife.

Polypoid granulations on the conjunctiva, warty excrescences at the lid-border, and similar growths are excised with curved scissors; if necessary, the small wound is touched with liquid chromic acid at the end of a probe.

3. Operations for Making a New Canthus; Canthoplastic Operations.—The object of these operations is either to reduce or to increase the transverse diameter of the palpebral aperture.

(a) **The Operation for Shortening the Palpebral Fissure (*Tarsorrhaphy* or *Blepharorrhaphy*).**—This accomplishes its object by uniting the opposing lid-borders for a short distance at the outer or inner canthus (*external* or *internal tarsorrhaphy*). The operation, as applied to the outer canthus, is performed as follows:

The surgeon seizes the border of the lower lid with a forceps near the outer canthus, and transfixes it with a narrow scalpel 2 mm. below the eyelashes in such a manner that the back of the blade is turned toward the canthus and its point emerges from the intermarginal surface of the lid-border just in front of the orifices of the Meibomian glands; pushing the blade along the lid-border by a steady sawing movement, the operator cuts from it a narrow strip, from 4-6 mm. in length, which must contain all the eyelashes. In the same way a similar flap is removed from the opposite border of the upper lid; the two opposing denuded surfaces (Fig. 342) are carefully united by two or three fine silk sutures, and the lids are kept immobilized by a bandage for two or three days, when the sutures are removed.

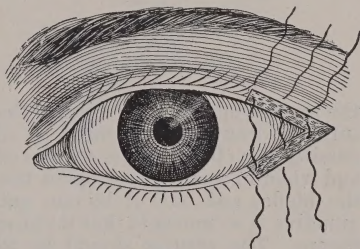


FIG. 342.—External tarsorrhaphy.

Internal Tarsorrhaphy.—In a case of paralysis of the orbicularis muscle, causing eversion of the lower tear-point, Dr. Arlt¹ has relieved the troublesome epiphora by a tarsorrhaphy at the inner canthus. From the tear-points toward the inner canthus a narrow strip of cutis was pared off and the wounds were united by two sutures.

Dr. H. D. Noyes² operated for the same purpose in the following manner: "I dissected up a parallelogram of skin above and below the canaliculi for a space which reached from the commissure to 3 mm. beyond the puncta. I turned the raw surfaces of the little flaps, raised from the respective lids, against each other and stitched through them. The puncta were thus turned inward and out of sight."

(b) The operation for enlarging the palpebral fissure (*canthotomy* or *blepharotomy*) is performed at the external canthus only.

If the enlargement of the fissure is required only temporarily for relieving the eyeball of the pressure of excessive lid-swelling in acute blennorrhea,

¹ Graefe and Saemisch: *Handbook*, vol. iii. p. 446.

² *Text-book of Ophthalmology*, 1894, p. 284.

or for the removal of an enlarged globe or a retrobulbar tumor, the operation consists simply in a horizontal incision through the commissure, the wound being allowed to close up again (*temporary canthotomy*).

But if the enlargement of the fissure is to be permanent, the reunion of the wound-edges must be prevented by lining them with conjunctiva (*permanent canthotomy*). The steps of the operation are as follows:

An assistant draws the temporal portions of the lids apart to make the external commissure stand out as a firm vertical ridge. The surgeon inserts the one blade of blunt-pointed straight scissors between the commissure and globe, and pushes it in a horizontal direction toward the wall of the orbit; next the scissors are shut, and with one firm stroke the entire thickness of the commissure is cut through. The bleeding is usually profuse, but easily controlled by pressure; sometimes, however, it is necessary to use torsion upon a small artery. Owing to the traction of the assistant upon the eyelids, the transverse incision is immediately changed to a vertical rhomboid wound (Fig. 343), whose temporal side is represented by the skin and the bulbar side by the conjunctiva. Skin and conjunctiva are then united by sutures to keep the palpebral fissure permanently enlarged. Three sutures are applied—one uniting the center of the wound where the new canthus is to be, and one suture above and one below it.

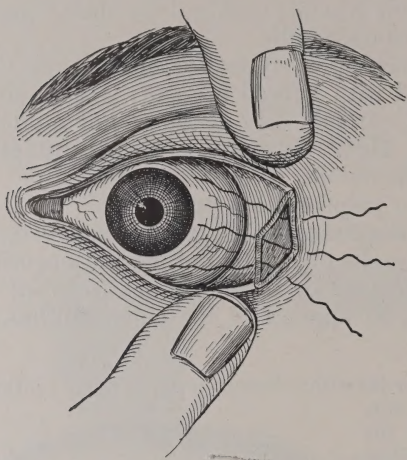


FIG. 343.—Canthotomy.

Before these sutures are passed it is necessary to loosen the conjunctiva from the underlying tissues. Seizing the conjunctival border of the wound with forceps, the surgeon draws upon it until he distinctly feels the resistance of the ligament; then, passing the closed blades of curved scissors into the wound, he feels for the ligament, and when he has found it opens the scissors just far enough to get the ligament between the blades, and cuts it by one quick stroke. As soon as the ligament is cut the conjunctiva is so movable that it can easily be united with the skin-borders of the enlarged fissure. The sutures should be tied rather loosely, lest they cut through the swollen tissue too soon. Bandaging is not necessary. On the third or fourth day the sutures can be removed.

Operation for Epicanthus.—The best results are obtained by the modified v. Ammon's operation, devised by Dr. Knapp¹ in 1873.

A rhomboidal piece of skin, over an inch in length and nearly two-thirds of an inch in width at its broadest part, is excised on the root of the nose. The skin at both sides of the wound is carefully undermined, and when the bleeding has subsided the wound is united by silk sutures. Dr. Knapp covers the wound with plaster strips to protect it from the child's hands, for immediate union is of the greatest importance to avoid unsightly scars on the nose.

MAJOR OPERATIONS.

This group comprises operations—

1. For the correction of malposition of the eyelids (entropion and ectropion);
2. For the reconstruction of the partly or totally destroyed lid;
3. For the relief of ptosis.

I. Operations for Entropion and Trichiasis.²—Instruments.—Small scalpels, curved scissors, mouse-toothed forceps, needles, needle-holder,

¹ *Archives of Ophthalmology*, vol. iii. p. 53.

² The so-called trichiasis represents merely the most advanced stage of entropium.

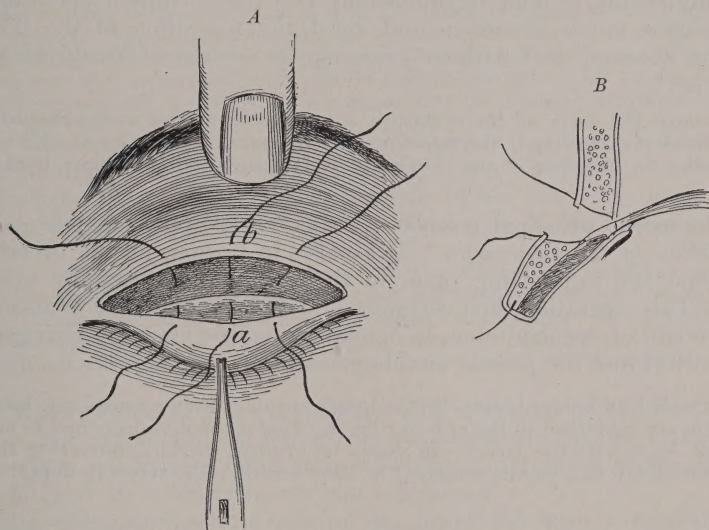
and silk Nos. 1 and 3. The lid-clamp and lid-plate are not absolutely required, though used by many operators.

The chief object of all entropion-operations is to remove the offending eyelashes from contact with the eyeball. This can be accomplished in two ways: either the whole inverted lid-border is turned up and secured in its normal position by a permanent tension from a fixed point above, or the eyelashes alone are turned up to their normal direction and supplied with a support below to prevent their reinversion.

1. The principle of relieving entropion by permanent tension upon the lid-border finds its most correct and successful application in the operation of *Anagnostakis and Hotz*.¹

The operation is performed on the upper lid as follows:

While an assistant fixes the skin at the supra-orbital margin the operator, seizing the center of the lid-border with fingers or forceps, draws the lid downward to put its skin well on a stretch, and makes a transverse incision through skin and orbicularis muscle from a point 2 or 3 mm. above the punctum lachrymale to a point 2 or 3 mm. above the external canthus. This incision (Fig. 344, *A*) divides the lid-skin in a line



FIGS. 344, 345.—*A* and *B*, operation of Anagnostakis and Hotz.

parallel to and a little below the upper border of the tarsal cartilage, and is therefore from 4 to 8 mm. distant from the free border in the center of the lid. The skin and muscular layer are now dissected from the incision down to the roots of the eyelashes, and, while an assistant is holding the edges of the wound well separated, the operator seizes with forceps and excises with curved scissors the muscular fibers running transversely across the upper border of the tarsus. Next the sutures are inserted. Three sutures are usually sufficient—one in the center of the wound and one at each side of the central suture. The curved needle, armed with black silk No. 3, is first passed through

¹To the former belongs the credit of having been the first (*Annales d'Oculistique*, 1857) to declare that in order to be effective, uniform, and lasting the skin-tension applied to the lid-border must proceed from a fixed point so located that it maintains the same distance from the lid-border in all the various positions and movements of the lid, and the only point which fulfils these anatomic conditions is the opposite border of the tarsal cartilage. But this valuable suggestion and the operation based upon it did not find among the oculists the recognition they deserved. Twenty years later Dr. Hotz was led by his own independent investigations to adopt the same views (*Arch. of Ophth.*, viii. p. 249), and to suggest an operation in its chief features identical with that of Anagnostakis.

the wound-border of the lid-skin (Fig. 344, *a*); then it is thrust through the upper border of the tarsus and returned through the tarso-orbital fascia just above this border; and finally it is carried through the upper wound-border (Fig. 344, *b*). When these sutures are tied the skin is drawn upward and fixed to the upper tarsal border (Fig. 345, *B*), and this slight traction is sufficient to turn the inverted lid-border and eyelashes to their normal position; and, as the skin becomes firmly united with the tarsal border, the tension thus produced upon the lid-border is permanently secured.

The sutures should, of course, not be tied until all bleeding has ceased and the wound is thoroughly cleansed; they may be removed on the third day. Under aseptic dressings the wound heals by first union, even if, as sometimes occurs, secondary hemorrhage or edema causes considerable swelling for several days. Should, however, suppuration occur, the sutures should at once be taken out to give free exit to the pus; and if the suppuration is promptly subdued, a fair result may still be hoped for, because the contraction of the cicatrix unites the skin with the tarsal border.

This operation can be performed also on the lower lid; only that on account of the smallness of the tarsus the sutures are passed entirely below it through the tarso-orbital fascia.

In the higher degrees of entropion (trichiasis) additional surgical measures are often necessary: if the palpebral fissure is abnormally contracted, canthotomy should be done in connection with the entropion operation; and if the tarsus is much shrunken and rigid, the reposition of the lid-border cannot be accomplished without *grooving the cartilage* (*Streetfeild-Snellen's operation*).

Just above the roots of the eyelashes a transverse, narrow wedge-shaped strip is removed from the cartilage; the resulting groove makes it easy for the lid-border to turn up under the traction of the skin when it is sutured to the upper border of the tarsus.

2. The second principal method of relieving entropion may be called the *reconstruction of the lid-margin*. It consists in turning up the inverted eyelashes alone, and supporting them in their normal position by a new lid-margin. This operation, first suggested in 1873 by Spencer Watson's complicated double-transplantation, has gone through numerous changes before it was evolved into the present simple procedure.

The inverted lid-border is split by the intermarginal incision, great care being taken that *all* cilia are contained in the anterior layer. This incision is deepened so much that the anterior layer with the lashes can easily be everted, thereby converting the intermarginal incision into a gaping wound (Fig. 346) several millimeters in depth.

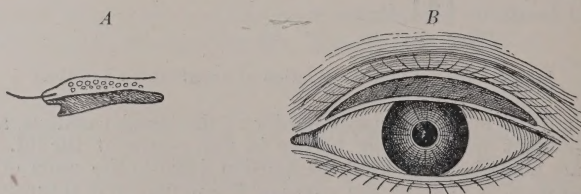


FIG. 346.—Reconstruction of lid-border.

This groove is to be filled either by a strip of mucous membrane or a skin-graft. The graft must be of the same length and width as the intermarginal wound.

The strip of mucous membrane is cut out with a few clips of a pair of curved scissors from the inner surface of the under lip, and placed at once on the wound and pressed into position with a pledget of cotton wool or gauze.

The skin-graft is cut out from the integument behind the ear, the incisions penetrating obliquely just into the corium. It is at once transported to the lid and pressed into the groove. If the graft should be too large, it should be trimmed down with a pair of small curved scissors until its edges are even with the margin of the wound. Sutures are unnecessary, but both eyes should be bandaged for twenty-four or forty-eight hours, until the graft is adherent.

The writer prefers skin-grafts, because the normal intermarginal space is lined by skin, not by mucous membrane; because skin-grafts are less likely to mortify; and because filling the entire depth of the wound makes a more substantial new lid-border. The use of skin-grafts is often objected to on the ground that the fine hairs in the transplanted strip would irritate the eye, but if the grafts are cut as described above, they never grow any hairs. If subsequently any hairs are found in the newly-made lid-margin, a careful inspection will prove that they grow from the posterior edge of the lid-margin, or, in other words, they are cilia which the operator when making the intermarginal incision has left in the posterior margin of the wound.

The two methods of entropion-operation here described can relieve all degrees of entropion; in the worst forms the best results are obtained by the combination of both methods.

This latter plan is certainly superior to the *Jaesche-Arlt operation*, in which also skin-tension is combined with the transplantation of the cilia.

The lid-margin is split by the intermarginal incision; next a second incision is made 5 mm. above and parallel to the ciliary edge, and a third incision is carried in a curve from one end of the second incision to the other end, and the semilunar piece of skin is removed. The bridge containing the eyelashes is detached from the underlying cartilage by careful dissection, so that when the margins of the gaping skin-wound are drawn together by fine sutures the bridge is shifted upward. This produces along the lid-margin a gap which is covered by a piece of skin (Waldauer's modification).

The objectionable features of this operation are that the new intermarginal space is abnormally broad, and that the excision of the lid-skin seriously disturbs the natural appearance and movements of the lid. In many instances the shortening of the lid-skin has made the closure of the lids impossible.

Burow, Green, and others, believing in an incurvation of the tarsus as the chief factor in the production of entropion, practise a transverse incision from the conjunctival side through the entire thickness of the tarsus to straighten the supposed incurvation. These operations are seldom permanently successful, and leave on the conjunctival surface a thick scar which is often the source of a persistent irritation to the eye.

II. Operations for Ectropion.—The eversions of the lid calling for operative correction are the senile ectropion and the various forms of eversion from the contraction of cicatrices following extensive tissue-destruction in the lid and its vicinity (*cicatricial ectropion*).

Senile ectropion occurs only in the lower lid from a relaxation of its tissues associated with a lengthening of its free border. Unless the lid-border is shortened, the reposition of the everted lid cannot be successfully accomplished. This accounts for the unsatisfactory results attained by the suture-operations (Snellen, Argyll-Robertson, and others) which attempt to overcome the eversion by the traction of sutures carried from the conjunctiva near the fornix through the entire thickness of the lid, and tied upon the cheek over a piece of small rubber tubing.

Shortening the lid-border is accomplished by *Adams's operation*:

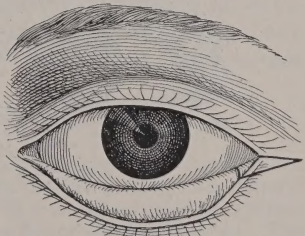


FIG. 347.—Shortening of the lid-border.

A wedge-shaped piece is excised from the entire thickness of the lid and the margins of the wound drawn together by sutures. If, as originally practised, the piece is excised from the center of the lid, the contraction of the scar produces an unsightly notch in the lid-border; this disfigurement is avoided by making the excision at the external canthus (Fig. 347).

The Kuhnt-Müller Operation.—A very neat operation for the same purpose was designed by Prof. Kuhnt in 1883, and modified by L. Müller in 1893.

A deep incision is made by an iridectomy-knife into the center of the lid-margin to split the lid-substance into two portions—the one portion containing the conjunctiva and tarsus, and the other portion containing the soft tissues and the skin. From the first portion a triangular piece is dissected out by two incisions (Fig. 348, *A*, *ac* and *bc*) converging toward the fornix. The two portions of the lid are further separated toward the external canthus by carrying the lance from and under the margin *bc* toward *d*. Now the V-shaped wound of the tarsus is closed by one or two sutures, and then the long stretch of the skin-margin (*da*) is "gathered up" with the much shorter margin *db* of the tarsus by sutures; the proper mode of their application is best understood by a reference to Fig. 348, *B*. Where these sutures are tied the skin puckers a little between each suture, but the process of cicatrization will efface every trace of this unevenness and restore a perfectly smooth lid-margin.

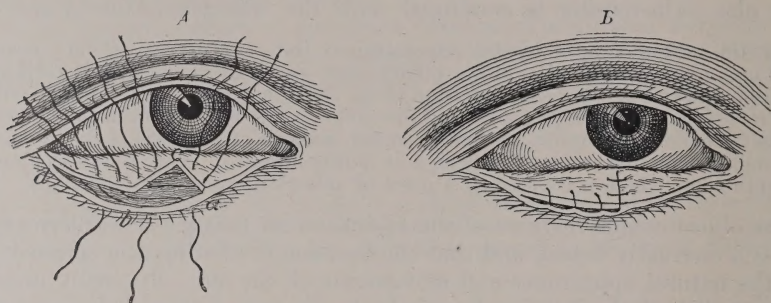


FIG. 348.—*A*, shortening of lid-border after manner of Kuhnt and Müller; *B*, Kuhnt-Müller operation, final stage.

In the operations for *cicatricial ectropion* the first step should always be to liberate by careful dissection the everted lid from all cicatricial adhesions so thoroughly that its reposition is possible without the least restraint or resistance.

Cicatricial ectropion of the lower lid presents two problems:

1. Its border, being stretched and abnormally lengthened, must be reduced to the proper size.

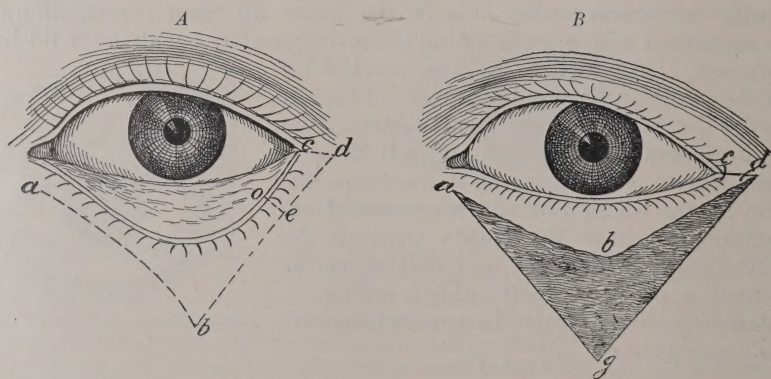


FIG. 349.—*A*, Arlt's operation for cicatricial ectropion of lower lid; *B*, final stage.

2. The replaced lid must be provided with a solid support below to hold it in its normal position.

In many instances these problems can be successfully solved by *Arlt's operation* (Fig. 349, *A* and *B*).

The incisions *ab* and *bd* are made so that they form at *b* an acute angle. These incisions are carried right through the cicatricial tissues; the flap *abd* is carefully dissected up to the lid-border, and the lid released from all cicatricial restraints, so that it can easily be brought into its normal position. Next the lid-border is shortened at the external canthus by removing the piece *coed*, making an incision *co* along the edge just behind the eyelashes on the conjunctival side and the crosscuts *cd* and *oe*. If now the lid-border is lifted up into its proper position, the wound-margins *oe* and *cd* are brought in apposition and held together by two sutures.

The reposition of the lid leaves below it the open wound *abdg* (Fig. 349, *B*), which must be filled with some solid material to furnish a good support to the lid according to the second indication stated above. If the adjacent integument is sound and elastic, the support of the replaced lid can be furnished by drawing the margin *ag* and *gd* together from *g* upward, and by uniting also a portion of the margin *ag* with *ab* and *gd* with *bd* to a Y-shaped cicatrix.

If this plan cannot be adopted, *Wolfe's method of grafting a skin-flap without a pedicle* upon the wound should be practised.

The edges of the lower and upper eyelids are united by three ligatures, and the ends of the ligatures are drawn up and fixed upon the forehead by strips of adhesive plaster. The shape and size of the skin required must be carefully cut out in lint. A piece of lint is then laid upon the forearm and the shape traced by the point of the knife, *making it one-third larger all around to allow for shrinking*. This flap is excised and spread out on the left forefinger to remove from it with sharp scissors all areolar tissue to leave a white surface. The flap so prepared is put upon the wound and moulded into position. No sutures are used; several pieces of lint or gauze wrung out of hot water are laid upon the flap and secured by a bandage. *The eye should not be disturbed for the first three days*, after which the dressing should be carefully removed, the last layer being well soaked with hot water in order that it may be removed easily without deranging the flap. It may then be dressed every twenty-four hours. The ligatures of the eyelids should not be removed before six weeks.

This operation is superior and preferable to all the numerous ingenious methods of transplanting flaps with pedicles from the face, for it is free from the serious disadvantage they possess—to wit, that if the flap sloughs the disfigurement of the face is worse after the operation than before.

Operation for cicatricial ectropion of the upper eyelid presents an additional problem of great interest—namely, to restore its mobility. On this account the selection of a proper material to replace the lost skin of the lid is of the greatest importance. This material should be so thin as to mould itself to the surface of the lid, and so light and pliable as not to impede the movements by its weight and thickness. For these reasons the transplantation of skin-flaps from the temporal region cannot be recommended. *Wolfe's* flaps have been used with fairly good results, but the lid always looks heavy and cannot be elevated to the full extent.

Thiersch's method of skin-grafting yields better cosmetic results.

The lid, being completely liberated from the cicatricial adhesions, is drawn down and fastened to the cheek by three ligatures passed through the lid-border. The wound is temporarily covered with a gauze compress wrung out of a warm solution of sodium chlorid ($\frac{1}{2}$ per cent.) while the grafts are being cut from the flexor side of the arm. The surgeon grasps the arm between the thumb and fingers of the left hand to draw the skin tense, and, holding the razor in his right hand, he lays its blade flat upon the well-wetted surface of the arm, and presses it down just enough to make its sharp edge bite into the skin, but no deeper than the papillary layer. By slow and short sawing motions the blade is steadily pushed on in the papillary layer until a piece of epidermis of the desired size has been gathered on the razor-blade.

During this "shaving process" an assistant drops salt solution upon the blade and pushes with a probe the skin-shaving back from the edge of the razor. To cut the

shaving off, the edge of the knife is turned up, while the assistant presses the probe flat down upon the shaving near the edge of the razor-blade. Now the compress is removed from the lid, the wound is carefully cleansed of all coagulated blood, and the skin-shaving is transferred directly from the razor to the lid-surface. For this purpose plenty of salt solution is dropped on the razor to keep the graft floating: if, now, the edge of the razor near its point is brought in contact with the border of the wound, the solution will run off from the razor and carry the graft with it; but as soon as the solution begins to flow and the edge of the graft has come in contact with and clings to the wound-border, the razor is drawn from under the graft across the wound, by which maneuver the skin-graft floating from the razor is at once spread out smoothly over the lid-surface. It is not difficult to cut shavings from $1\frac{1}{2}$ to 2 inches in length and from 1 to $1\frac{1}{2}$ inches in width if only the knife-blade is operated by a steady hand and moved in the same plane. When the whole wound is well covered with these skin-shavings two layers of strips of silk protective, moistened with the salt solution, are placed in position. They should be half an inch wide and long enough to lap over the wound-border on both sides; one layer is placed in a transverse direction and the second layer in a longitudinal direction. These strips are covered with a compress which is to be kept wet with salt solution. The sound eye should also be bandaged.

This first dressing should remain undisturbed for two days. To remove it the compresses and strips of protective are thoroughly soaked with salt solutions; the grafts are rinsed with the same solutions, and fresh strips and compresses are applied. After four or five days the bandage may be removed from the sound eye, at the end of one week the ligatures may be cut, and during the second week the grafted lid needs only to be daily rubbed over with iodoform ointment. After the second week no further treatment is required. The grafted skin undergoes a gradual contraction of about one-fourth of its area, but if this shrinkage has been anticipated by the operator, it will not affect the perfect cosmetic success of the operation.

Transplantation of Cicatricial Skin to Replace the Integument of the Lid.—For cases where the eyebrow is partially destroyed and the supraorbital region largely covered by cicatricial tissue the author has made the new skin of the replaced lid from this cicatricial skin.

In case of complete ectropion of the upper lid (Fig. 350) the procedure was as follows:¹

The border of the everted upper lid of the left eye was drawn up and fixed to the temporal portion of the supraorbital margin, and above it a large stretch of cicatricial skin extended far into the frontal and temporal region. The absence of the temporal

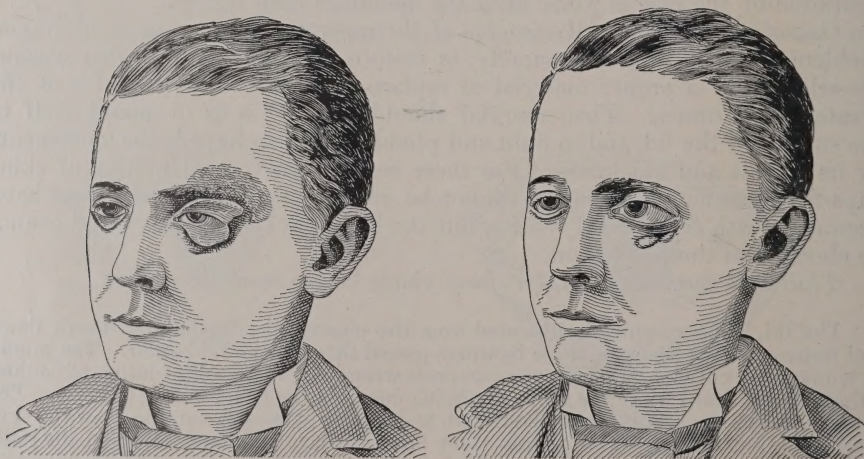


FIG. 350.—Showing restoration of the upper lid.

half of the brow made the following operation possible: From a point (*a*, Fig. 351) near the inner canthus an incision was carried obliquely upward past the end of the eyebrow,

¹ Case reported to the *American Medical Association* in 1896.

well up into the cicatricial skin above the supraorbital margin, and then continued at a considerable distance from the lid-border in a curved line downward to a point (c) about 6 mm. from the external canthus. The large skin-flap (abc) mapped out by this

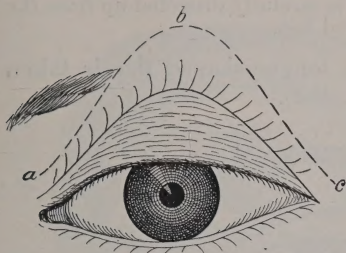


FIG. 351.—Hotz's transplantation of cicatricial flap.

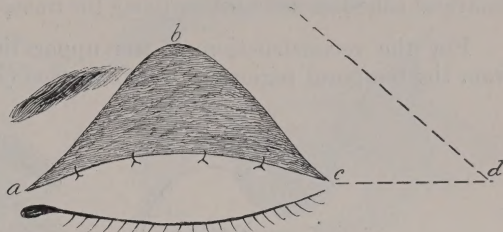


FIG. 352.—Second stage of Hotz's transplantation of cicatricial flap.

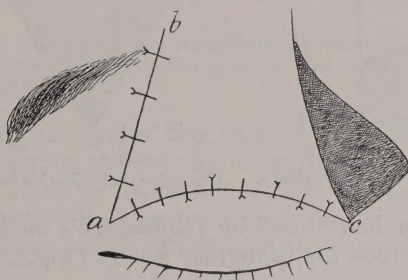


FIG. 353.—Final stage of Hotz's transplantation of cicatricial flap.

incision was carefully dissected from the underlying scar-tissue down to the lid-border, with which it was left connected. The lid then was released from all cicatricial adhesions and replaced in its normal position.

The cicatricial skin-flap (abc, Fig. 351) contracted considerably as soon as it was detached from its basis; but as this shrinkage was anticipated by cutting the flap of very large dimensions, it was still sufficiently large to cover the whole surface of the lid. It was spread over this surface, and its margin (ac, Fig. 352) was fixed by four sutures to the upper border of the tarsus, and the resultant wound (abc) above the lid was covered by a skin-flap (bcd) from the temporal side, the margin bc being united to ab, and de to the margin ac, Fig. 353.

The great advantage of this operation lies in the fixation of the new lid-skin to the upper tarsal border. This union makes the new skin an integral part of the lid, and constitutes a protective barrier to prevent tissue-contraction, which may take place in the supratarsal region, from disturbing the position of the lid.

III. Operations for the Restoration of the Lid (Blepharoplasty).—If the lid is partly or totally destroyed (by injuries, extirpation of tumors, ulcerations, etc.), the defect is repaired by the transplantation of skin-flaps from the vicinity. The operative procedures are as numerous as the lesions vary in character and extent, and each case must be studied well to designate the method best suited for its conditions. In general, it may be said that the results of blepharoplasty present a far better appearance on paper than in flesh.

The following methods may serve as working patterns :

Eversbusch's Method for Making an Entire New Lid.—A skin-flap of suitable shape and size is cut in the vicinity, and the wound as well as the under surface of the flap is covered with Thiersch skin-shavings. A piece of silk protective being placed upon the

wound, the flap is put back in its original place, and left there under proper aseptic dressings until the Thiersch grafts are adherent. Then the cicatrix along the orbital margin is excised, and the skin-flap being laid across the eyeball, its edge (which has been previously freshened up) is sutured to the wound along the orbital margin.

If a portion of the conjunctiva is preserved, this is carefully dissected up from the cicatricial adhesions and used for lining the transplanted flap.

For the reconstruction of the upper lid a tongue-shaped flap is taken from the temporal region—*Fricke's method* (Fig. 354).

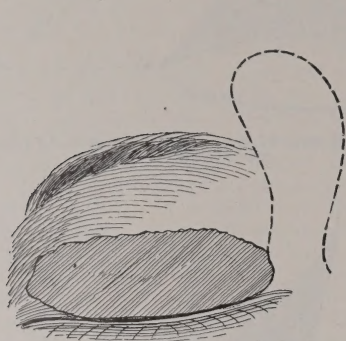


FIG. 354.—Fricke's method of blepharoplasty.

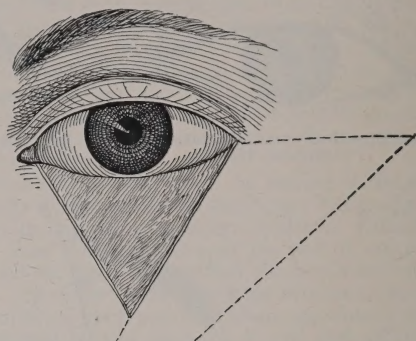
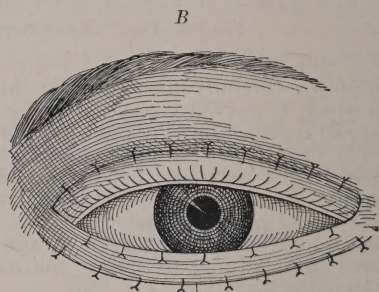
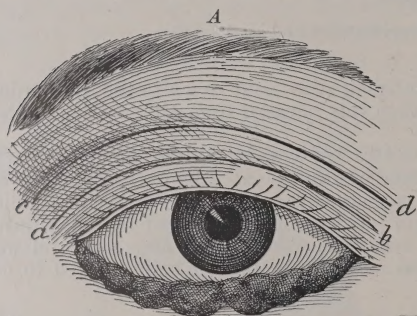


FIG. 355.—Dieffenbach's method of blepharoplasty.

The lower lid can be restored by *Dieffenbach's method* of sliding a flap taken from the cheek upon the triangular wound (Fig. 355), or by



FIGS. 356, 357.—Landolt's method of blepharoplasty.

Landolt's Method (Figs. 356, 357).—Two parallel incisions (*ab* and *cd*), which at both ends reach a few millimeters beyond the canthi, are made through skin and orbicularis of the upper lid, and this bridge, being dissected from the tarsus, is drawn down to take the place of the lost lower eyelid. The lower edge of the flap is sutured to the skin along the infraorbital margin, and its upper edge is united with the conjunctiva. After union has taken place the connections of the skin-bridge with the upper lid are divided.

If only a portion of the lower lid is lost, the remaining portion may be moved over into the defect, and, if the defect is very large, a skin-flap can be drawn over from the opposite side to be joined with the transplanted lid-portion—*Knapp's method* (Fig. 358).

For partial destruction of the upper lid Landolt has devised the following ingenious method (Fig. 359):

The nasal portion of the upper lid being lost, the surgeon splits the remaining lid-portion in its entire extent into two layers, the anterior layer containing the skin and muscle, the posterior layer containing the tarsus and conjunctiva. An incision made

through the anterior layer from the external canthus obliquely upward to the eyebrow allows the anterior layer to be shifted toward the nasal side, where it is united by sutures with the nasal margin of the original lid-defect; sutures are also put into the

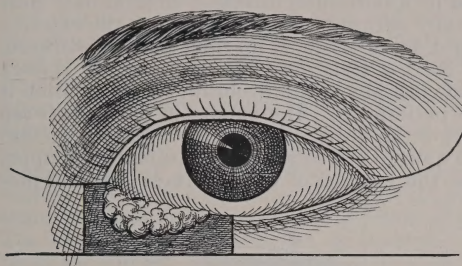


FIG. 358.—Knapp's method of blepharoplasty.

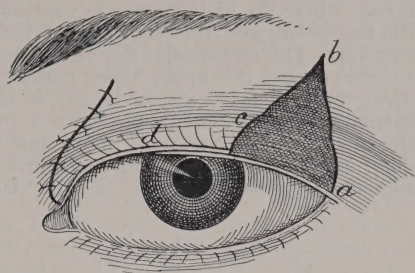


FIG. 359.—Landolt's restoration of a partially destroyed upper lid.

lid-margin from *c* to *d* to reunite the transplanted anterior layer with the posterior layer. The triangular wound (*abc*) resulting from the sliding of the anterior layer is covered by Thiersch's skin-grafts.

Operations for Coloboma of the Lid.—Congenital and traumatic colobomata of moderate extent can usually be rectified by a careful union of the freshened edges. Extensive lacerations of the lid, however, often produce so great a displacement of the severed lid-portion that its reposition requires a regular transplantation, as, for instance, in the following case :

In September, 1886, a young man received a deep cut by a piece of glass, completely dividing the temporal third of the upper lid of the left eye. In November he presented himself with a long oblique scar in the upper lid, with its temporal portion so displaced that its edge ran straight upward. To relieve this deformity the scar was excised from *a* to *c*, and a flap was formed by the deep incisions *ce* and *eg*. This flap, being well

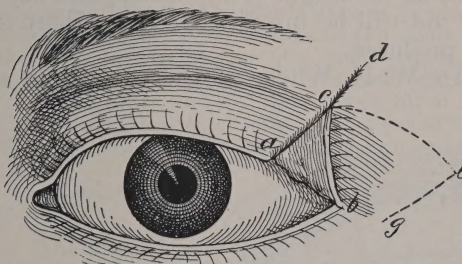


FIG. 360.—Replacement of lacerated lid according to Hotz.

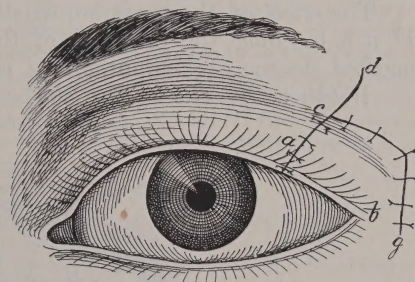


FIG. 361.—Result of replacement of lacerated lid.

mobilized, was then turned so as to bring the lid-edge *bc* into its normal position; the wounds were then closed by uniting the edges *ce* with *ac* and the neighboring skin with *ge*. The result was very satisfactory.

IV. Operations for Ptosis.—Patients suffering from paralysis of the levator palpebrarum instinctively learn to elevate the lid to a certain degree by the aid of the frontalis muscle. Its contractions, drawing the eyebrow and the integument between the brow and eyelid upward, exert indirectly a traction upon the lid by which a moderate elevation of the lid is accomplished. To increase this vicarious action of the frontalis muscle upon the upper lid is the aim of the following ptosis operations :

Panas's Operation.—The upper lid being stretched upon a horn plate, a transverse incision, following the furrow above the lid, is made through skin and muscle to expose the tarso-orbital fascia. From near either extremity of this incision a vertical incision (Fig. 362) is carried downward to a point 2 or 3 mm. below the upper border of the tarsus, where the one incision is continued in a horizontal direction to terminate near the tear-point, and the other one horizontally outward to terminate near the external canthus. The rectangular flap thus mapped out is dissected up from above downward, so as to expose the upper tarsal border. Next a transverse incision, slightly convex upward and about 2 cm. in length, is made just above the eyebrow. This incision is carried through all the tissues down to the periosteum. The cutaneous bridge between the two horizontal incisions above and below the brow is undermined, and the rectangular skin-flap is pushed under this bridge upward and attached by sutures to the upper edge of the upper incision. In order that the traction of these sutures shall not pro-

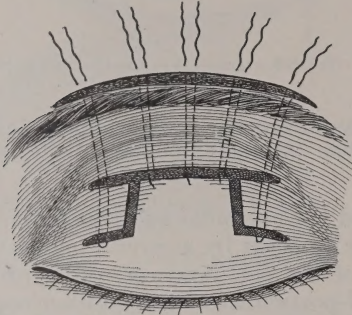


FIG. 362.—Panas's operation for ptosis.

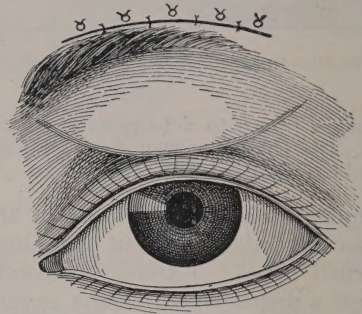


FIG. 363.—Panas's operation concluded.

duce ectropion, an additional suture is applied at each side. These lateral sutures are passed through the tarso-orbital fascia and conjunctiva near the upper tarsal border, but do not include the skin, and carried under the skin upward to emerge from the upper margin of the frontal incision. The wound is dressed with antiseptic dressing, and the sutures are removed after four or five days.

The effect of the operation depends on the length of the rectangular flap. If it is too long, the elevation of the lid will be insufficient; if too short, a marked degree of lagophthalmos is produced.

Wilder's Operation (Fig. 364).—Dr. W. H. Wilder of Chicago has in a

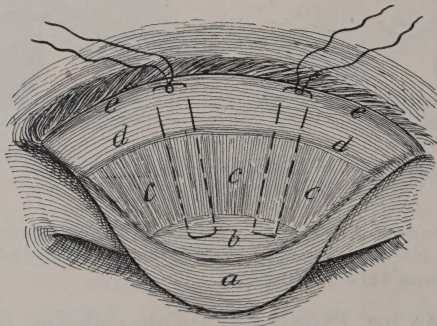


FIG. 364.—Wilder's operation for ptosis: *a*, lower lip of wound drawn down, exposing (*b*) tarsus and (*c*) tarso-orbital fascia, in which gathering stitches are placed; *d*, orbital margin; *e*, upper lip of wound, into the deep parts of which sutures are finally passed.

number of cases relieved the ptosis by folding upon itself the tarso-orbital fascia ("the suspensory ligament of the upper lid") and by establishing a firm adhesion between the fascia and frontalis muscle:

An incision $1\frac{1}{2}$ inches in length is made a little above and parallel with the orbital margin through all the tissues down to the periosteum, and should be so placed that the resulting scar will be concealed by the eyebrow. Retractors being used to draw down the lower lip of the wound, the skin and orbicularis muscle are separated from the fascia by careful dissection until the tarsus is brought into view. Two fine sutures of sterilized catgut or silk, armed at each end with a curved needle, are then passed in the following manner: the needle is introduced deep enough into the tarsus to secure a firm hold at a point about at the junction of the outer and middle third and a little distance from its upper edge. It is then drawn through, and several gathering stitches are taken upward in the tarso-orbital fascia, after which the needle is made to pass through the muscle and connective tissue of the upper lip of the wound. The other needle on the same suture traverses a parallel course in the same manner, entering the tarsus about 3 mm. from the point of entrance of the first, and emerging in the tissue above, thus making a loop by which the lid may be drawn up. The second suture is passed in the same way, making a loop at the junction of the middle and inner thirds of the tarsus. The requisite elevation of the lid may be now secured by drawing on the loops and tying the sutures, after which the ends may be cut off. The lower lip of the wound is now replaced and united to the upper with fine sutures. The slight scar that remains after healing is almost entirely hidden when the eyebrow grows again. As the buried sutures become capsulated additional strength is given to the bands that hold up the lid.

The various operations aiming at increasing the effect of the frontalis muscle by subcutaneous ligatures are unreliable and uncertain in their effect, like all operations done in the dark. But the excision of an oval piece of skin should never be practised for this purpose, because it produces a hideous lagophthalmos.

If the action of the levator muscle is not entirely lost, the principles of tendon advancement and tendon resection as practised in squint operations may be employed, and are made the basis of the methods of Eversbusch, Snellen, and Wolff.

In *Eversbusch's operation* the advancement is produced by folding the tendon upon itself, like the advancement of Tenon's capsule.

Midway between the lid-margin and the eyebrow a horizontal incision is made through all the tissues down to the fascia. The edges of the wound are dissected up to expose well the tendon, which there is blended with the tarso-orbital fascia. Four mm. above the upper border of the tarsus a small vertical fold of the center of the tendon is then taken up in the loop of a double-armed thread, and both needles are passed vertically downward between the tarsus and orbicularis, brought out at the lid-margin 2 mm. from each other, and tied over a small bit of rubber tubing. A similar suture is passed through the nasal and temporal portions of the tendon respectively; the skin-wound is closed by sutures before the tendon-sutures are tied.

*Snellen's operation*¹ is a tendon resection.

The upper border of the tarsus is exposed by a transverse incision and the orbicularis fibers are pushed upward and downward. The exposed fascia is then incised at some distance above the tarsal border, and three or four needles are thrust through the tendon and passed from above downward to emerge again through the upper border of the tarsus. But before the needles are drawn out the piece of tendon between the tarsal border and the point of entrance of the needles is excised. Then the needles are drawn through and the threads tied.

*Wolff's operation*² combines tendon resection with tendon advancement, and is a decided improvement over Snellen's method.

The surgeon makes an incision through all the tissues along the upper border of the tarsus, and, lifting up in a vertical fold the central portion of the tendon expansion on the anterior surface of the tarsus, he cuts at each side a vertical buttonhole, through

¹ Report of the German Ophthalmol. Society, at Heidelberg, 1883.

² *Ibid.*, 1896.

which two strabismus-hooks are slipped under the tendon, so that the one hook is placed close to the insertion and the other hook so far above it that the distance between

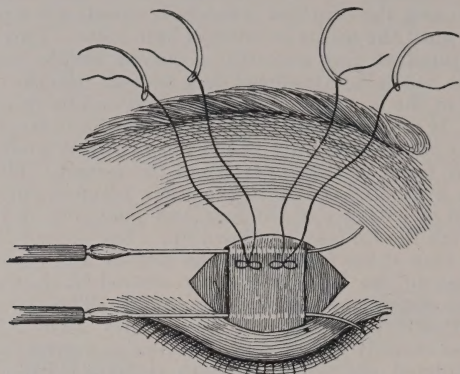


FIG. 365.—Wolff's operation.

the two hooks represents the piece of tendon to be resected. Two double-armed catgut sutures being put through the tendon just below the upper hook, the tendon is cut transversely below the sutures. Both ends of each suture are then carried behind the tendon-stump and passed through the line of insertion, tied, and cut short; the skin-wound is closed over them by silk sutures.

The success of the operation depends upon the accurate dosage of the tendon-resection; the resected piece should measure exactly as many millimeters as the vertical diameter of the palpebral aperture of the affected eye is smaller than that of the normal eye.

Operation of Ptosis Adiposa or Atonica.—In this affection the lid shows neither any superabundance of adipose tissue nor any imperfect action of the levator muscle; but the skin has lost its connection with the aponeurosis and the upper border of the tarsus, and therefore is not drawn back with the tarsus when the lid is opened, but falls down over the lid-border like a heavy curtain (Fig. 366). To relieve the deformity by cutting away this skin-curtain would be a grave mistake, because it would leave the skin so short that the lid could not be closed. But

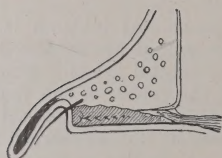


FIG. 366.—Operation for ptosis adiposa.

the deformity can be perfectly relieved by reattaching the skin to the upper border of the tarsus by means of the sutures employed in the author's operation for entropion (see page 549).

OPERATIONS UPON THE CONJUNCTIVA, CORNEA, AND SCLERA; ENUCLEATION AND EVISCERATION.

BY CHARLES W. KOLLOCK, M. D.,

OF CHARLESTON, S. C.

THE conjunctiva, being a highly vascular membrane, heals rapidly after injury, and so loosely is it attached to the eyeball that an extensive loss may be replaced by dissecting it from the ball in the vicinity of a wound and drawing the flaps together by sutures. No evil effects are produced by this procedure, and in many cases no visible cicatrix remains. With the conjunctiva of the lids, however, less liberty can be taken, for a loss of the covering in this part may result in entropion, or perhaps a narrowing of the palpebral fissure. Large wounds of the conjunctiva, after thorough cleansing, should be closed by sutures, and require but little after-treatment beyond cleanliness and protection by closing the lid.

Foreign bodies that pass through the conjunctiva are often difficult to remove on account of their entanglement in its meshes, and when a sharp instrument is used in the attempt to remove them *subconjunctival hemorrhage* generally occurs and obscures the field of operation. This is especially the case with grains of powder. The easiest method of dealing with such cases is to seize the body with forceps through the conjunctiva and snip off the entangling part, which causes but a small loss of tissue, and the wound heals without leaving a scar. Grains of powder may be removed in this way when not too numerous; otherwise by *electrolysis*, as advised by E. Jackson (see also page 368).

Operations for Pterygium.—The instruments used in these operations are a stop-speculum, fixation- and dissecting-forceps, sharp-pointed knife, small scissors, strabismus-hook or probe, needles, needle-holder, sutures, etc.

Operation.—The anesthesia produced by cocain is sufficient for this operation, which is performed as follows: (1) Thorough removal of the corneal portion of the growth may be accomplished by shaving or dissecting it away with a sharp knife, and then scraping (Deschamps) off the remnants carefully, or by destroying them with the thermo-cautery or by the application of pure carbolic acid (Alt). The method advised by Prince is also effective, and consists in grasping the growth with forceps near the corneal attachment, and by a series of slight jerks its roots or prolongations are withdrawn from beneath Bowman's membrane and even from between the corneal layers. No opacity remains when this is carefully done, nor does the cornea become inflamed. Next to divulsion, the method of scraping the remnants from the cornea with a knife is preferable to the use of the cautery, as it is difficult to limit the action of the latter agent.

The next step is the disposition of the body of the growth. It may be separated at its borders from the conjunctiva proper as far back as the caruncle, and then *excised*; or it may be *transplanted* beneath the conjunctiva, loosened for this purpose either above or below, and fixed in its new position by a suture passing through the growth and its conjunctiva; or it may be split from apex to base, and one-half transplanted above and the other below the opening, as advised by Knapp.

Others (Boeckmann, Hotz) advise unfolding and spreading out the growth after separating it from the cornea, first removing all subconjunctival tissue; which is a most important step in any procedure. Boeckmann fastens the reposed conjunctiva (pterygium) to the head of the internal rectus muscle by a suture, and leaves the small tri-

angular and denuded space near the cornea to heal by cicatrization, which, he contends, will prove an effectual barrier to a future growth. Hotz, after reposition, covers the

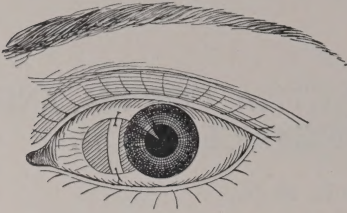


FIG. 367.—Showing position of graft, narrower than wound, but long enough to reach across it.

denuded spot with a graft taken, after the method of Thiersch, from the inner surface of the forearm or from behind the ear. This graft is cut slightly smaller than the area to be covered, and is placed in position with or without sutures according to circumstances.

Hobbs and others advise removal by means of the *electro-cautery*. The growth is grasped by forceps near the cornea and lifted from the sclera; a curved needle or probe is passed beneath it, and then the neck is burned through with the cautery-tip at a cherry-red heat. The subconjunctival tissue is drawn out and excised, and the corneal end is scraped away or touched

by the cautery. A cross-stitch unites the conjunctiva near the cornea.

In all cases of removal or transplantation of the growth the conjunctiva should be loosened above and below and the edges closely united by sutures.

Dressing.—After thorough cleansing with warm bichlorid or boric-acid solution the eye is closed with sterilized gauze and cotton, which are held in place by any form of light bandage or by adhesive strips. The dressing may be renewed every day, and sutures should remain as long as they do not irritate, which is usually four to five days. When removing sutures it is advantageous to have the eye under the influence of cocain, for a sudden movement may cause the edges of the wound to separate. The simple introduction of the speculum may also cause this accident, so that whenever possible it is safer to have the lids held apart by the fingers of an assistant or even by the patient if he is not too nervous. After the removal of the sutures the dressing may be left off, and the eye, which is often quite sensitive, protected by tinted glasses.

Complications are rare after this operation. Ulceration of the cornea has occurred, and should be treated by the usual methods. Occasionally a small growth of granulation-material springs from the wound, but it is easily snipped off with scissors or it may be contracted by astringent solutions. When the growth has extended well over the cornea a hazy spot is apt to remain after its removal. Pterygium often returns, and may, under ordinary circumstances, be again removed.

Symblepharon.—Instruments necessary for the operation are—stop-

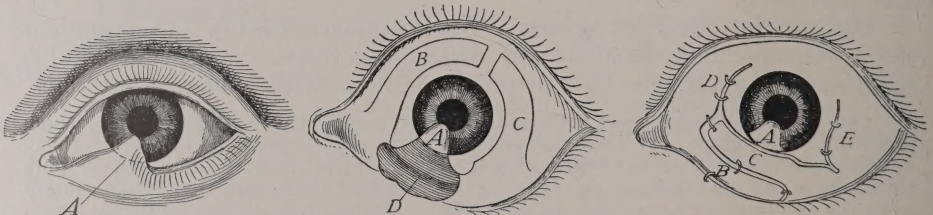


FIG. 368.—Teale's operation for symblepharon.

speculum, vulcanite spatula, fixation- and dissecting-forceps, probe, scissors, sutures, needles, needle-holder, etc.

For the simpler operations cocain may be used, but when the adhesions are extensive ether or chloroform is more satisfactory.

Operations.—The slight forms of symblepharon known as *symblepharon anteri* are easily cured by separating the attachment and preventing its recurrence by the frequent passage of a probe between the points. Pooley and Searles each report a case in which the formation of symblepharon was prevented by using a glass or rubber shield which fitted over the globe between the lids, and which was left in place, except during short intervals for cleansing, until healing took place.

There are several methods of operating when adhesions are extensive and involve the fornix (*symblepharon posterius*). Symblepharon is often incurable.

(1) The lid is separated from the ball and the dissection is carried well back to the fornix (Arlt). A suture armed with two needles is passed through the separated end; the needles are then passed from the bottom of the cul-de-sac through the lid to the cheek. Tightening the suture draws the flap down and brings the conjunctival surface next to the raw surface of the ball. The ends of the suture are tied over a piece of cork or drainage-tube.

(2) *Teale's Operation*.—Sliding flaps from the adjacent conjunctiva are brought over the denuded portions and sutured in position (Noyes and Teale). The operation is readily comprehended by attention to the accompanying illustrations (Fig. 368).

(3) Riverdin covers denuded surfaces with small pieces of mucous membrane taken from the mouth.

(4) Harlan has devised the following operation where there is extensive adhesion to the lower lid: The adhesion is freely dissected until the upward movement of the ball is entirely unimpaired, and an external incision, represented at *AB* in the accompanying cut, along the margin of the orbit is carried through the whole thickness of the lid, which is thus separated from its connections except at the extremity. A thin flap, *CD*, is then formed from the skin below the lid, care being taken to leave it attached at its base-line by the tissue just beneath *AB*, as well as at the extremities. On this attachment it is turned upward as on a hinge, bringing its raw surface in contact with the inner surface of the lid, and its sound surface presenting toward the ball, and held in this position by suturing its edge to the margin of the lid. In dissecting up the flap the incisions are carried more deeply into the orbicularis muscle when the base-line *AB* is nearly reached, to enable it to turn more readily. The bare space left by the removal of the strip of skin is nearly covered without strain by making a small horizontal incision, *DE*, at its outer extremity and forming a sliding flap (Fig. 369).

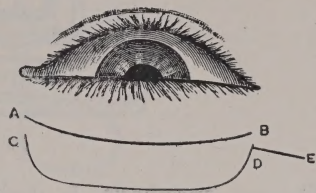


FIG. 369.—Lines of incision in Harlan's operation for symblepharon.

(5) For very extensive adhesions an opening may be made below the attachment and a piece of lead wire inserted, which is left until a fistulous opening is formed, when one of the above operations may be performed (Himly).

(6) Large raw surfaces from extensive adhesions may also be covered by skin-grafts after Thiersch's method (Hotz).

Dressings.—After minor operations it is sufficient to bandage the eye, and it should be kept closed until the sutures are removed. After transplantations the eye should not be disturbed for three or four days, unless there are signs of irritation, and both eyes should be bandaged.

Complications are due to the failure of grafts to unite and to renewal of adhesions.

Symblepharon posterius due to trachoma is scarcely amenable to surgical treatment.

Transplantation of Rabbit's Conjunctiva.—Wolfe first suggested this mode of dealing with extensive adhesions between the lid and eyeball, and several operators have performed the operation with beneficial and even surprising results. General anesthesia is necessary, as the operation is tedious.

The eye and appendages are cleansed and the adhesions are divided. Bleeding is controlled by pledgets of absorbent cotton saturated with hot water and placed in the cul-de-sac. Two rabbits are anesthetized, in case any accident should happen to one. The size of the graft having been calculated, four sutures are introduced at its corners before it is separated, because after removal it rolls upon itself and it is rather difficult to recognize the proper surface. The graft having been separated, it is rapidly transferred to the denuded area and carefully stitched in position.

Ankyloblepharon is readily relieved when the edges of the lids only are united, but when the adhesions involve the ball also, treatment is of little avail.

Operations for Trachoma.—*Expression* of trachomatous bodies is

performed in various ways by different surgeons and according to the gravity and duration of the case. The roller-forceps devised by Knapp (Fig. 370)



FIG. 370.—Knapp's roller-forceps.

and the modifications of this instrument have aided very much in the thorough performance of this operation.

Where follicles are discrete, as in follicular disease, they are easily expressed between the thumb-nails, or preferably by dissecting-forceps.

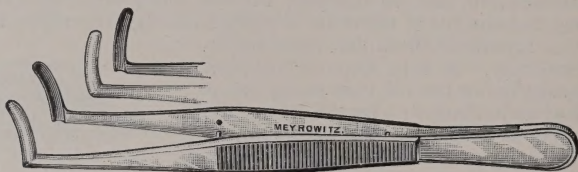


FIG. 371.—Noyes's trachoma-forceps.

General anesthesia is desirable for the surgical treatment of trachoma, though there are those who prefer to operate under the influence of cocaine.

Operation of Expression.—The lid is grasped with forceps near the ciliary border and rolled upon itself until the conjunctival surface is well exposed. The roller-forceps are then used as follows: one blade is pushed well up into the retrotarsal folds while the other is placed near the ciliary edge. The morbid material in the conjunctiva is then thoroughly expressed by a milking process, each portion being subjected to the squeezing. The retrotarsal folds may be treated separately by still further everting the lid and drawing them out. When the conjunctiva near the edge of the lid is to be expressed, one blade should be placed upon the cutaneous surface. The surgeon should wear protecting glasses, as the expressed material often flies out suddenly and to a considerable distance.

After-treatment.—After careful cleansing with warm bichlorid solution iced compresses are applied to the lids for several hours to prevent pain and swelling. The conjunctiva is not as much mutilated as might be expected by this rough handling, and but little reaction follows. Adhesions are very apt to form, and should be broken down by the daily passage of a probe through the cul-de-sac. The subsequent treatment of the case requires the application of a solution of nitrate of silver (gr. v-f $\frac{3}{4}$), and later that of a crystal of sulphate of copper.

George Lindsay Johnson has described the following operation for trachoma:

The lid is everted over a vulcanite spatula and held tense in this position by a double hook inserted near its edge. With a tri-bladed scalpel the conjunctiva is incised parallel to the free border of the lid from end to end. The instrument is then moved



FIG. 372.—Three-bladed scarifier.

so that the last blade shall pass through the foremost cut, and so on until the entire surface has been incised. The thicker the lid the deeper the cuts, and *vice versa*. Bleeding is controlled by cotton compresses saturated with hot water. An *electrolizer*, connected with a Stöhrer's battery of twenty cells and having two platinum blades, is next used. The blades pass through the incisions made by the scalpel. About thirty milli-

ampères are used, and a thick foamy cream at once arises about the blades. Strong currents should be avoided. The lids are then washed, sprinkled with a 5 per cent. solution of cocain, dusted with calomel, and smeared with an ointment of hydronaphthol and vaselin, 1 to 800. Inflammation and swelling are controlled by iced compresses. There is considerable discharge and sloughing for forty-eight hours. Care should be taken not to injure the cornea.

The after-treatment consists in using boric-acid wash and the ointment of beta-naphthol and vaselin. No entropion or ectropion has resulted.

Grattage is an operation recommended for trachoma by Abadie, Darier, and other French surgeons. As the operation is necessarily quite painful, ether or chloroform should be used.

The lid is everted and held by forceps (Fig. 373), as in the operation for expression, and the conjunctiva is freely incised from the ciliary border to the fornix, and from end to end of the lid, by the tri-bladed scarificator (Fig. 372) or a similar instrument. The

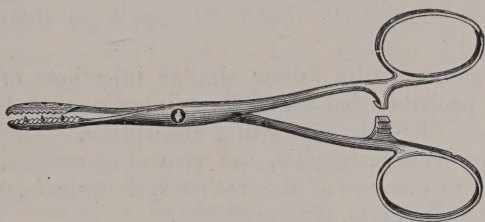


FIG. 373.—Forceps for grattage.

incised surface is next thoroughly scrubbed with a nail-brush that has been saturated in a strong solution (1 : 500) of bichlorid of mercury. By this proceeding all trachomatous material is washed out, and the lids are then treated by cold applications, as described on page 564. The same care must be exercised to prevent the formation of adhesions.

Excision of the Cul-de-sac.—This method of treatment is very old, but Galezowski in 1874 brought it again prominently before the profession. Stephenson also advocates its performance in certain cases, and reports a number of successful operations. The operation advised by him is as follows :

The lid is everted, and two moderately strong sutures are passed through the extremities of the fold. The sutures are held by an assistant, who by their manipulation keeps the parts "on the stretch." An incision is now made along the attachment of the fornix to the tarsal conjunctiva with blunt-pointed scissors, but should never go beyond the anterior layer of the fold. This layer is freed from its attachments, and the dissection into the subconjunctival layer is carried as far back as is deemed necessary. The operation is completed by cutting transversely through the posterior layer of the cul-de-sac, which comes away with the sutures. Bleeding is often profuse, but may be arrested by twisting the vessels. Sutures are never employed to close the wound. The eye is cleansed and closed, and is not inspected for five or six days, unless complications arise.

Complications are of two kinds—viz. wound-granulations and ptosis. The former should be snipped off with scissors. The latter may be due to the swelling of the lid which naturally follows, and will soon disappear, or to interference with the tarsal insertion of the levator palpebræ muscle. Stephenson always excises the upper cul-de-sac, as it is more difficult to reach for treatment than the lower, and never advocates the operation for cases that can be cured by other means.

Choice of an Operation.—Expression is especially valuable in cases of spawn-like granulations and diffuse hyaline infiltration. It may be used in cicatricial trachoma with patches of hyaline infiltration. Grattage may be employed in cicatricial trachoma and in cases characterized by sclerotic masses of trachomatous tissue. It is inferior to expression preceded by scarification. The indications for excision of the cul-de-sac have been given.

Peritomy, or syndectomy, is performed for getting rid of a thick pannus. A narrow strip of conjunctiva 2 to 4 mm. in width is removed from around the cornea, and all vessels going to the cornea are divided.

Kenneth Scott proposes a substitute for peritomy, as he believes the latter operation is rarely a success, in cases of vascular cornea. By the aid of a magnifying-glass he is enabled to divide with a Graefe knife every vessel passing to the cornea. He slits them throughout their entire length, which destroys the vessel and further anastomosis is prevented.

Subconjunctival Injections of Germicides.—After thorough conjunctival antiseptis and anesthesia have been secured, a fold of conjunctiva is seized with a pair of forceps about 8 mm. from the corneal margin, and the point of a hypodermic or Pravaz syringe charged with the germicide is introduced, very much in the same manner as when an ordinary hypodermic injection is given, and 2 to 4 minims of the fluid are injected. The strength of the solution varies with different operators. Of bichlorid 1:2000 or 1:4000 may be employed. Trichlorid of iodine and cyanuret of mercury may be used in the same way.

Precisely the same results follow similar injections of physiologic salt solution, and it is probable that all of these injections act by stimulating the lymph-channels, and therefore promoting absorption. They act favorably at times in iritis, irido-cyclitis, scleritis, and corneal ulceration. They have also been recommended in diseases of the retina and optic nerve, but the author doubts their value under these circumstances.

OPERATIONS UPON THE CORNEA.

Foreign Bodies in the Cornea.—Small particles of dust, cinders, iron, steel, emery, stone, etc. frequently adhere to or become partially or wholly imbedded in the cornea.

When simply adherent to the corneal surface or but slightly imbedded the foreign body is easily wiped off with a wisp of cotton or scraped away by a sharpened match-stick or *clean* wooden toothpick. Such means are preferable to steel instruments in these cases, as they are less liable to injure the cornea. When the body is more firmly fixed, however, it is necessary to use the ordinary steel spud or cataract needle (Fig.

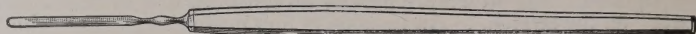


FIG. 374.—Spud.



FIG. 375.—Angular lance-knife.

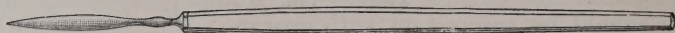


FIG. 376.—Lance-knife.

374). Bodies which have sunk below the surface are by no means easy to extract, for a slight pressure suffices to force them into the interior chamber.



FIG. 377.—Johnson's magnet for removing foreign bodies from cornea.

When, therefore, such a condition exists, a small lance-knife (Figs. 375, 376) should be entered beneath the body to prevent its going nearer the chamber. It is then cut down

upon and grasped by forceps or pushed from its position with a small probe or spud. W. B. Johnson has devised a magnet for such cases. Cocain anesthesia is sufficient.

After-treatment.—Especially care should be taken in the after-treatment of these corneal wounds, for it not infrequently happens that poisonous germs are introduced and infectious ulcers follow, causing abscess and loss of vision from resulting leukoma or loss of the entire eye from panophthalmitis. After removal of the body the wound and eye should be carefully cleansed with an aseptic solution, atropin instilled, and the eye closed by a bandage to prevent reinfection from the air; all instruments should be carefully sterilized.

Removal of Gunpowder Grains from the Cornea.—E. Jackson treats these cases by the galvano-cautery, as follows:

A small cautery-tip, such as is used for cauterizing corneal ulcers, is brought to a white heat and the imbedded powder-grains are touched in rapid succession, sufficient time being allowed for destroying tissue. The resulting scars are not worse in appearance than the stains. When possible the operation should be done early and before diffusion of the carbon takes place (see page 368).

Paracentesis of the Cornea.—The instruments required for this operation are a stop-speculum or elevator, fixation-forceps, paracentesis-needle, and a small spatula.

Operation.—The anesthesia of cocain is sufficient, except with children, for whom ether, chloroform, or bromid of ethyl should be used. The eye is fixed by grasping the conjunctiva with the forceps as near the point to be opened as is possible, because by this means the eye can be held more firmly, the opening made gradually, and a sudden evacuation of the aqueous humor prevented. The needle is entered within the

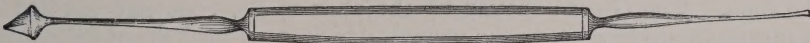


FIG. 378.—Paracentesis-needle.

corneo-scleral border at right angles to the surface, and as the blade is pushed onward the handle is slightly depressed in order to avoid wounding the iris and lens-capsule. Next the needle is gently withdrawn, allowing at the same time a gradual escape of the aqueous, so that the iris shall not be swept into or against the wound. Careful cleansing, the instillation of atropin or eserin, as the case may be, and a light bandage, which should be worn two or three days, generally comprise all measures needful in the way of treatment. The operation may be repeated when necessary.

Complications.—Prolapse of the iris into the wound may occur, and when it cannot be replaced with the spatula, it should be excised, unless the prolapse is very small or the iris rests against, rather than falls into, the incision.

Curetting the Cornea.—A small curette or spud may be used for this operation, which is done for indolent or spreading ulcers.

By the aid of a curette the necrosed tissue is carefully scraped from the sides and bottom of the ulcer, after which the ordinary treatment for corneal ulceration is followed. De Wecker and Santarnecchi (Cairo) advise what is called "*hydraulic curetting*" as a substitute for the ordinary methods and the use of the cautery. A syringe having a small nozzle is filled with a solution of bichlorid of mercury (1:1000), which is then thrown in a steady stream upon the ulcer and gradually washes away the necrosed tissue. Santarnecchi claims that it is more thorough and less dangerous than ordinary curetting and the use of the cautery, as injury to the sound tissues is much less likely to occur.

Application of the Actual Cautery.—For this purpose a platinum-tipped probe of the galvano-cautery may be used.

The point, having been brought to a red heat, is lightly applied to the floor and sides of the ulcer, care being taken not to perforate the anterior chamber. The area to be cauterized is colored green by dropping upon it a solution of fluorescein (see page 145).

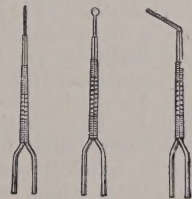


FIG. 379.—Galvano-cautery points.

The **after-treatment** consists in the use of atropin and mild aseptic washes, such as boric acid and salt. The application of a bandage depends upon the quantity of the discharge.

Saemisch's Section.—The instruments necessary are a stop-speculum, fixation-forceps, v. Graefe knife, spatula, and perhaps a small syringe.

Operation.—The pupil should be dilated as much as possible, and if the patient is a child general anesthesia is necessary. The eye is steadied by grasping the conjunctiva with the forceps while the knife is entered, edge out, in the healthy tissue near the ulcer. The point is passed through the anterior chamber and emerges at a corresponding spot beyond the ulcer, when the intervening corneal tissue is cut through, allowing the pus and aqueous humor to escape.

Sometimes the pus is caught between the lips of the wound, but is easily removed with a spatula or iris-forceps, or by washing out the chamber with any specially devised syringe charged with normal salt solution. The iris should be replaced as well as possible, but synechiæ are likely to result.

The **after-treatment** consists in cleanliness, the instillation of atropin, and the application of a bandage until the cornea has healed. The operation may be repeated as often as the pus re-forms.

Complications are synechiæ and the resulting leukoma, which latter is due to the ulceration rather than the incision. Panophthalmitis and entire destruction of the cornea may result if the ulceration is not checked.

Conical Cornea; Staphyloma Pellucidum.—There are various operations for this deformity, all of which have for their object the removal of the cone. Von Graefe shaved off the apex of the cone and applied the solid nitrate-of-silver stick to the wound, which, as it healed, caused contraction and diminution of the cone. Bowman accomplished the same result by means of a trepan, and Knapp has devised a special point for the galvanocautery, with which the cone is cauterized as deep as Descemet's membrane, avoiding, if possible, entrance into the anterior chamber (Fig. 380).



FIG. 380.—Knapp's cautery-point for conical cornea.



FIG. 381.—Tattooing-needle.

After healing, an iridectomy is usually necessary. The scar left by the cautery may be tattooed—a procedure which not only improves the appearance of the eye, but also the vision, by excluding unnecessary light. It may be necessary to repeat the operation, which is preferable to running the risk of destroying the eye by attempting too much at first.

Tattooing the Cornea.—The instruments required are a stop-speculum, fixation-forceps, and tattooing-needle (Fig. 381).

Operation.—Thorough anesthesia of the cornea is essential in order that the ink may be driven well into its layers. The India ink should be of the consistency of paste and plentifully applied to the leukoma, as it soon fades when thinner. The pigment is then pricked into the cornea over the area to be covered, after which the excess is washed away by a boric-acid solution. Atropin is next instilled and a light bandage is applied. The reaction subsides within a few days, and the operation may be repeated, if necessary, after all inflammation has disappeared. Different colored inks may be used to match the varying colors of the irides. Tattooing is also useful for covering colobomata which admit too much light to the eye.

Wounds of the Cornea.—Incised wounds usually heal without trouble, it being simply necessary to cleanse the eye carefully, to bring the lips of the wound accurately together, to replace the iris if it has fallen into the wound, and to apply a bandage. Eserin or atropin may be used accord-

ing to the position of the wound. If the prolapse continues and cannot be replaced, it should be excised. Large gaping wounds, whether incised or lacerated, may be closed with sutures, which should be composed of very fine silk.

De Wecker has advised the following method for closing and protecting large wounds of the cornea: The conjunctiva is dissected from the corneal limbus and beyond the attachments of the recti muscles. A suture is then passed in and out near its edge, which, when tightened like a string at the mouth of a bag, draws the conjunctiva over and entirely covers the cornea. It should remain until the cornea has healed, when it may be dissected loose. Adhesions do not take place, except, perhaps, in the line of the wound, and these are readily freed.

Von Hippel's Operation for Transplanting the Cornea.—In cases of central leukoma von Hippel has transplanted a graft from the cornea of a rabbit, but the results have not been very satisfactory, because the transplanted cornea has also finally become opaque. He restricted the operation to those cases where the entire corneal thickness was not involved—in other words, where the leukoma was not totally adherent.

Operation.—A general anesthetic should be used for patient and rabbit. The eye having been prepared, the trepan is gauged so that it shall not enter the anterior chamber. It is placed accurately over the center of the cornea, and by touching the spring the cut is quickly made. The plug is lifted out by the aid of special forceps and cut off with a Graefe knife. In a like manner the plug is cut from the rabbit's eye and quickly transferred to the patient's. After cleansing, both eyes should be bandaged and the patient kept quiet in bed for a few days.

Complications may be ulceration of the cornea and general infection of the eye.

Operations for Closing Scleral Wounds.—Wounds of the sclera are common near the corneal border, over the ciliary body, and on the upper surface of the ball. Owing to the frequent involvement of the ciliary body, extreme care must be exercised in their management.

Small punctured wounds require no special care beyond the usual antiseptic precautions; but if exposed, they should be covered with the conjunctiva. Small incised and lacerated wounds, when inclined to gape or when their edges are separated by a bead of vitreous humor, should be closed, after the prolapsed vitreous has been excised, with small animal sutures introduced through the outer layers in order to avoid wounding the inner coats of the eye. The conjunctiva is to be sutured over the scleral wound with animal or silk sutures. Large scleral wounds may at times be approximated simply by closing the conjunctiva over them, but it is probably safer to suture the sclera to avoid the danger of staphyloma. Care must be taken that the ciliary body and choroid are not imprisoned in the wound. The subsequent treatment requires cleanliness and bandaging until healing is complete.

Complications arise from injuries to the ciliary body, choroid, and retina, which may cause sympathetic ophthalmia and separation of the retina. Prolapse of the vitreous interferes with healing.

Sclerotomy.—The instruments for this operation are a stop-speculum, fixation-forceps, Graefe knife, and spatula.

Operation.—A Graefe knife is entered in the sclera about 1 mm. from the cornea, and, passing through the anterior chamber, emerges at a corresponding point on the opposite side. The cut is made upward by a to-and-fro motion, as in the operation for removing cataract, until a narrow bridge is left connecting the sclera with the cornea. The knife is then withdrawn carefully to prevent, if possible, the prolapse of the iris, which is apt to occur, and which should then be excised (Fig. 382).

This operation is not as effective as iridectomy, and Fuchs says should only be performed under the following conditions: 1. Glaucoma simplex, with a deep anterior chamber and without distinct elevation of tension. 2. Inflammatory glaucoma, when the iris through atrophy has become so narrow that one cannot hope to perform excision of the iris that would be according to rule. 3. Hemorrhagic glaucoma. 4. Hydropthalmos. 5. Instead of a second iridectomy in those cases of glaucoma in which the increase of tension returns in spite of an iridectomy performed according to rule (compare with page 578).

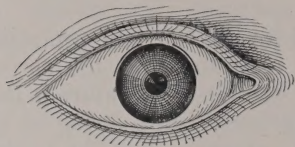


FIG. 382.—Lines of incision in sclerotomy.

Posterior Sclerotomy.—The incision should be placed so as not to wound the ocular muscles or endanger the ciliary body, and should, therefore, not approach the cornea nearer than 6 or 7 mm. The cut is made with a Graefe knife from behind forward, so as to correspond with the direction of the scleral fibers. There is probably less danger from infection if the incision in the sclera is not directly under that in the conjunctiva. When it is desired to produce a fistulous opening the incision should be made near the equator, as healing is less likely to take place here than farther forward.

Posterior sclerotomy is indicated in cases where the anterior chamber has been obliterated and iridectomy or anterior sclerotomy cannot be performed, for separation of the retina, for staphyloma, and for those cases in which reduction of tension is indicated and other operations are not available. In cases of corneal staphyloma it may be necessary to repeat the operation a number of times before satisfactory results are obtained.

Sclerectomy, as described by H. Parinaud, is for the purpose of obtaining less resistance from the sclera, more efficacious drainage, and the formation of a staphyloma when desired.

Operation.—At a point near the equator a curved needle is plunged into the external layers of the sclera, which are then slightly elevated. With a Graefe knife, held parallel to the needle, a flap is cut, at the bottom of which the choroid should be visible. It is advisable not to cut entirely through the sclera, though this may be punctured later if thought necessary.

Operations for Staphyloma.—Small staphylomata of recent formation may frequently be cured by pressure from well-applied bandages, which should be kept in place until the cornea has regained its tonicity. When this proves unsuccessful an iridectomy may be performed at or near the point of bulging; after this the eye must be bandaged until healing is complete and the parts are strong.

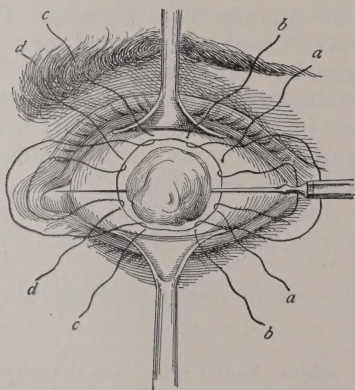


FIG. 383.—De Wecker's operation for staphyloma.

A staphyloma involving the entire cornea is difficult to treat successfully, and many methods of operating have been devised. Probably the most effective is entire excision of the growth; though the safer, but more tedious method, which sometimes succeeds admirably, is by posterior sclerotomy.

For the operation by excision the following instruments are necessary: a stop-speculum, fixation-forceps, Beer's knife, scissors, needles, and sutures. Ether or chloroform should be administered.

De Wecker and Critchett both, after having inserted needles or sutures through the base of the staphyloma to prevent loss of vitreous, excise the staphyloma with the knife and scissors and allow the lens to escape. De Wecker closes the wound by drawing the conjunctiva together over it, while Critchett passes the sutures through the sclera and draws its edges accurately together. The conjunctiva is then closed over the scleral wound. Reference to the figures will make the steps of these operations evident, which are not now much practised, as evisceration with insertion of artificial vitreous is preferable (Figs. 383-385).

After-treatment.—The eye is dressed and kept closed for several days unless there are symptoms of inflammation. Healing is slow.

Complications.—Wounding the ciliary body may cause sympathetic ophthalmia, and a general infection may be followed by panophthalmitis.

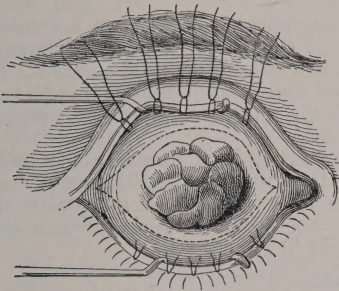


FIG. 384.—Critchett's operation for staphyloma.

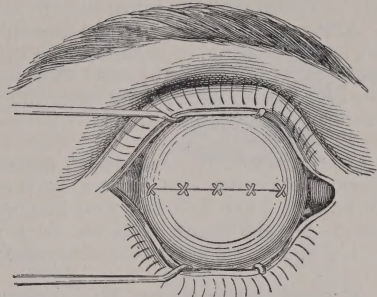


FIG. 385.—Stump after Critchett's operation for staphyloma.

Enucleation of an Eyeball.—Most operators prefer general anesthesia for this operation, but there are a few who advise cocain. J. J. Chisolm

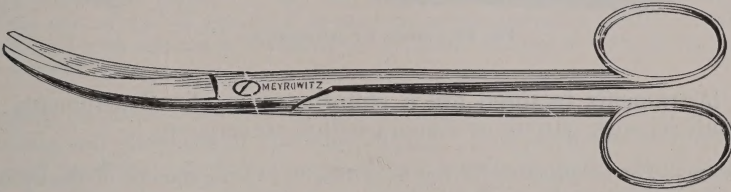


FIG. 386.—Enucleation-scissors.

speaks highly of bromid of ethyl. The instruments required are a stop-speculum, fixation- and dissecting-forceps, strabismus-hook, and enucleation-scissors (Fig. 386).

Operation—Bonnet's Method.—The conjunctiva is grasped by the forceps near the cornea, and with the scissors is loosened entirely around the latter and as near to it as possible. The dissection is then carried well back in every direction. The recti muscles are next caught up separately by a strabismus-hook and their tendons divided close to the ball. The scissors are now pressed close to the ball and dissect it from the orbital tissues on every side. The enucleation-scissors are then passed well back into the orbit until the points touch the optic nerve, when they are separated and the nerve is severed as far back as possible. The scissors may be entered from the nasal or temporal side. Care should be taken not to divide the nerve too close to the ball or the sclera may be perforated.

Vienna Method.—By this method the operation is much more quickly performed, but there is greater loss of orbital tissue, which prevents the

accurate fitting of an artificial eye. This operation, however, is to be recommended when for any reason a quick manipulation is necessary.

The conjunctiva is opened near the outer or inner margin of the cornea and dissected away over the attachment of the rectus muscle, which is caught up and divided. The scissors are then passed rapidly around the ball, dissecting it from the orbital tissues until the nerve is reached and divided. The arms of the speculum are opened and pressed back to force the ball from the socket. The conjunctiva, muscles, and orbital tissues are then easily divided by rotating the ball. If hemorrhage is profuse after enucleation, it should be checked at once by hot water to prevent the orbital tissues from becoming infiltrated. The hot water is best applied by saturating balls of absorbent cotton and forcing them into the orbit. Some operators suture the edges of the conjunctiva, though this is unnecessary.

After bleeding has ceased the orbit should be flooded with hot bichlorid solution (1 : 5000). A piece of sterilized gauze is placed next to the lids, upon this a good-sized pad of absorbent cotton (sterilized), and over these a roller bandage is tightly applied, care being taken to make the turns from below upward, so that the compress shall be forced into the orbit.

After-treatment.—When possible the dressing should be changed a few hours after its application, as it adds much to the comfort of the patient. The eye should be dressed every day, and the orbit thoroughly flooded with warm bichlorid solution. Rest in bed for two or three days after the operation is a safe plan to follow, though many surgeons do not require it. After three or four days the roller bandage may be replaced by a lighter form.

Complications.—Secondary hemorrhage rarely occurs, and may be controlled by applying hot water and tightening the bandage. Cellulitis, meningitis, acute mania, and tetanus have followed enucleation. In cases of cellulitis and meningitis deep incisions should be carried to the back of the orbit, hot applications should be made to the lids, and a free evacuation from the bowels should be encouraged.

Exenteration or Evisceration.—This operation should under no circumstances be performed upon an eye that may be capable of causing sympathetic ophthalmitis, and is therefore applicable to but a few cases.¹



FIG. 387.—Scoop for evisceration.

The instruments required are a stop-speculum, fixation-forceps, Beer's knife, small scissors, curette or scoop, needles, sutures, etc.

Operation.—The conjunctiva having been dissected to the equator of the eyeball, the cornea is excised by passing a Beer's knife through the corneo-scleral juncture from side to side and cutting out above, then reversing the knife and cutting down, or after the first incision with the knife the remaining flap is removed with the scissors. The contents of the globe are evacuated and the inner coats scraped away with scoop or curette. Hemorrhage is controlled by hot water and the cavity cleansed with hot bichlorid solution (1 : 2000 or 3000). It is very essential that every portion of the contents should be thoroughly removed and hemorrhage completely controlled, for under these conditions healing, which is necessarily slow, progresses more favorably. Prince advises cauterizing the scleral cavity with 95 per cent. carbolic acid to relieve pain and to hasten healing. The edges of the sclera are approximated accurately with catgut sutures, and the conjunctiva is closed with silk sutures.

Dressings and the **after-treatment** are the same as for enucleation, but the period of recovery is more protracted.

Evisceration of the Eyeball, with Insertion of an Artificial Vitreous (Mules's Operation).—Mr. Mules has modified the operation of

¹ In the opinion of the Editor, the sphere of evisceration is by no means so limited, although if in a case of sympathetic ophthalmitis or irritation already developed it was decided to remove the exciting eye, he would perform enucleation.

evisceration by the introduction of a glass ball into the cavity of the sclera. In general terms the operation is performed in the same manner as an ordinary evisceration, but certain special precautions require to be noted.

The conjunctiva having been dissected from the corneo-scleral attachment in all directions to the equator of the eyeball without disturbing the muscles, evisceration is performed, after abscission of the cornea, in the ordinary manner. A perfectly clean white scleral cavity must be secured, and hemorrhage absolutely controlled by packing the cavity with sterilized gauze saturated with a hot solution of bichlorid of mercury, 1:2000, and by frequently irrigating it with a tepid solution of the same drug. Sometimes the hemorrhage is more readily controlled with repeated dry packings of sterilized gauze than with hot solutions. A glass sphere (Fig. 389), of such size that it may be introduced within the scleral cup without difficulty, is selected, its introduction being facilitated by slitting the sclera vertically for about 4 mm. at the upper and lower corneo-scleral margins. The introduction of the sphere is further facilitated by the use of an instrument specially devised for this purpose (Fig. 388). The concluding steps of the operation consist in stitching the sclera vertically, the conjunctiva horizontally, dusting iodoform within the socket, and applying a full antiseptic dressing. Indeed, the greatest care should be exercised to secure absolute antisepsis during the operation and at the subsequent dressings.

After-treatment.—The patient should be confined to bed for at least three days, and both eyes should be band-

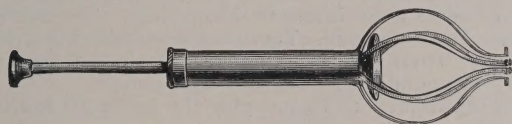


FIG. 388.—Instrument for introducing the glass sphere.

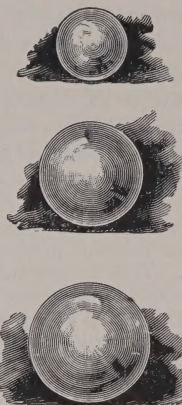


FIG. 389.—Glass balls for introduction into scleral cup after evisceration.

aged for forty-eight hours. At the end of this time there may be a daily dressing, and at the end of five or six days, or at most at the end of a week, the patient may be discharged from his room. Usually an artificial eye can be worn at the expiration of two weeks.

Complications.—Severe reaction occasionally follows, with mark edema of the lids and chemosis of the conjunctiva. The chemotic conjunctiva may be incised, and the reaction controlled by continuous iced compresses.

Early absorption of the sutures, if catgut is used, may cause the scleral wound to separate and the glass ball to extrude. Should this happen, the ball may be removed and the operation converted into an ordinary enucleation, or a still smaller ball may be placed in position and the scleral wound once more closed with catgut sutures.

The stump after a successful Mules's operation is so superior to that furnished by any other method that, if no contraindication exists, there should be no hesitancy in performing this operation; for even if the accident of extrusion of the ball should take place, the remaining stump is far preferable to any that could be formed after an ordinary enucleation. The danger that the glass ball may be broken is remote, although this accident has happened.

Other Operations for Support of Artificial Eye.—Claiborne and Belt advise *sponge-grafting* in the orbit for the support of an artificial eye. After removal of the eye a globe of sponge, about three-fourths the size of the eyeball, is inserted into the socket or Tenon's capsule. The recti muscles are then united over it and the conjunctiva over all. Suker prepares the

stump for an artificial eye by suturing the recti muscles together with catgut and the conjunctiva with silk.

L. W. Fox describes an operation for *implanting a glass ball* in an orbit from which the globe has been enucleated at some previous date. A horizontal incision is made through the conjunctiva and tissues of the orbit, which should be slightly less than the diameter of the ball to be inserted. The upper lip of the conjunctival wound is raised and dissected away by sharp scissors until a pouch is made for the ball, which is inserted after bleeding is controlled, and the opening closed by sutures. This operation is practically identical with the suggestion of Frost and Lang to introduce a Mules's sphere into Tenon's capsule after ordinary enucleation, and close the muscles and conjunctiva over it in the usual way.

Optico-ciliary Neurectomy.—This operation, like evisceration, was proposed as a substitute for enucleation, but has not, for two reasons, filled the place to which it was assigned: 1. It does not replace enucleation, because the danger of infection from such an eye is by no means prevented, as cases of sympathetic ophthalmia have occurred after its performance. 2. The operation is rather difficult to perform, and has been followed by softening and atrophy of the globe.

Operation.—An opening is made between the superior and external recti muscles, and the scissors, pressed close to the ball, divide the tissues until the optic nerve is found. This is caught by a strabismus-hook as far back as possible and divided. The optical end is then seized by forceps or hook and drawn to the opening. The nerve and all surrounding tissues are then cut close to the ball. There is considerable hemorrhage, and it is difficult to replace the ball. There is some prominence of the ball for a time, but it usually resumes its normal position after a shorter or longer period.

After-treatment consists in cleanliness and bandaging the eye until healing is complete.

Complications.—Abscess of the orbit and meningitis may follow from infection during the operation.

OPERATIONS ON THE IRIS AND THE CRYSTALLINE BODY.

By HERMAN KNAPP, M. D.,

OF NEW YORK.

General Precautions.—The patient should be free from acute disease and from exacerbations of chronic general disease. The time of the year makes a difference only in so far as constitutional infirmities are influenced by it; for instance, fat persons should avoid the hot season, patients with pulmonary and kidney disease the coldest winter months, etc. Cleanliness of the skin and hair, as well as regularity of the bowels, should receive due attention.

The operations on the iris and lens can be most conveniently performed on an operative chair, which can be moved (on casters), so that the best illumination of the eye, either by day or by artificial light, can be readily secured and disturbing reflexes avoided. For cataract-extraction it is of advantage to operate on the patient in his bed, if the bed can be moved to the source of light, because the patient will not be disturbed by taking him

from the chair to his bed. This advantage is counterbalanced by the greater ease the surgeon and his assistant enjoy when the patient is placed upon a chair.

The patient should keep as quiet as he can during the first twenty-four hours after the operation, for quietness is an important factor in obtaining primary union of the wound. He may, however, sit up in bed for his meals and get up for calls of nature. In case he is not nervous and his attendance good, the degree of success of the operation will be greater if for one or several days both eyes are bandaged; otherwise, the non-operated eye may be covered with a patch which the patient occasionally may raise.

No *septic condition* should be present in any organ of the patient at the time of the operation; in particular, the conjunctiva and the lachrymal sac must be free from suppuration. Chronic non-suppurative disease of these parts is no absolute counter-indication.

The operations should be done under aseptic conditions as perfect as we can have and make them. Immediately before the operation the eye and its surroundings are washed with soap, then with a 1 : 5000 solution of corrosive sublimate, with which also the edges and mucous surfaces of the everted eyelids are washed by means of pledgets of absorbent cotton.

Cocain-anesthesia is sufficient and preferable in most cases; only in children, nervous and unruly adults, and in cases of high eyeball tension, complete general anesthesia should be administered.

Besides a nurse, the operator should have at his disposal two or three trained assistants—one to take charge of the instruments, the second to hold

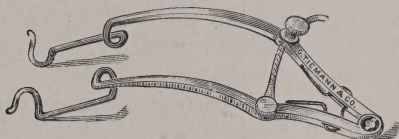


FIG. 390.—Eye-speculum.

the fixing-forceps and cleanse the wound, the third to throw day or artificial light on the eye with a hand-lens, which is indispensable in at least 50 per cent. of the operations.

The eyelids are kept open by a *wire speculum* that does not press on the eyeball, and is strong enough to prevent the spasmodic closure of the lids.

The eyeball is steadied with *fixing-forceps*, the teeth of which are numerous and large enough to be firmly inserted into the episclera. They



FIG. 391.—Fixing-forceps.

are provided with a catch that closes them fast, yet can be opened without a jerk.

OPERATIONS ON THE IRIS.

I. **Iridectomy**—*i. e.* *Excision of a Piece of the Iris*.—Its indications are twofold.

1. To Make a New Passage for the Rays of Light.—Artificial or Optical Pupil.—This is done—

(a) When the natural pupil is more or less occluded by malformation or disease.

(b) When the axial portions of cornea or lens—*i. e.* those situated right before or behind the pupil—are so opaque or misshaped as to intercept the rays of light or cast on the retina a less defined image than would be formed by light passing through a peripheric portion of the cornea and lens. This is the case in closure of the pupil, and opacities, or abnormities of curvature in the center of the surfaces of the cornea and lens (keratoconus and lenticonus). An artificial pupil should, however, never be made before an examination with a stenopeic apparatus by dilated pupil has positively demonstrated that the new pupil will afford better sight than the old. This precaution applies particularly to maculæ corneæ.

2. To Relieve and Cure Inflammations of the Eye and their Sequels.—Antiphlogistic or Curative Pupil.—This is done—

(a) In *chronic recurrent iritis*, when broad or circular synechiæ impede or prevent the current of the aqueous humor from the posterior to the anterior chamber. The strongest indication for an iridectomy is furnished by the so-called crater-shaped pupil, which when left alone will not only cause blindness, but the ruin of the eye by irido-cyclo-choroiditis, and may even have a prejudicial effect on the other eye.

(b) In all affections in which prolonged increase of eyeball tension is a pronounced symptom—*i. e.* in *primary and consecutive glaucoma*.

(c) To remove tumors (cysts, sarcomata, etc.) and foreign bodies if they are located in the anterior part of the eye, and cannot be removed without sacrificing a piece of the iris. Foreign bodies in the iris formerly were never removed without excising the piece in which they lay imbedded.

(d) As a step in ripening immature cataract, and as a preliminary operation for subsequent extraction of cataract (see later).

(e) To remove prolapses of the iris after injuries and operations. When a patient consults us with a fresh wound through which iris protrudes, it may be left alone if the lens is not injured and the wound is not situated in the ciliary region near to and concentrically with the border of the cornea. In prolapses, which happen frequently after cataract extraction, the protruded iris is apt to swell, become cystic, and in all cases produce a high degree of astigmatism. In such instances clean removal of the prolapse, and, if the latter is not fresh, deep excision of the iris, is the best treatment. Also in recent prolapses of the iris through a corneal wound a clean iridectomy, if it is still possible, can appropriately be done. If the iris cannot be disentangled from the wound and the prolapse is let alone, we frequently see an undisturbed recovery, with permanently good sight, follow the natural, clean elimination of the protruded iris by a process of constriction of the base and snaring off of the protruded part.

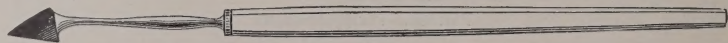


FIG. 392.—Lance-shaped knife.



FIG. 393.—v. Graefe's knife.

The special instruments for iridectomy are—a lance-shaped (Fig. 392) or a small (v. Graefe) cataract-knife (Fig. 393); an ordinary iris-forceps, curved



FIG. 394.—Curved iris-forceps.

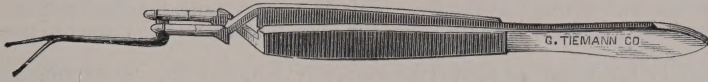


FIG. 395.—Mathieu's iris-forceps.



FIG. 396.—Curved iris-scissors.



FIG. 397.—Grooved spatula and probe.

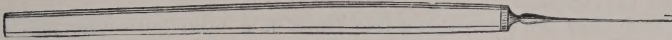


FIG. 398.—Tyrrell's hook.

(Fig. 394), or its modification by Mathieu (Fig. 395); a pair of curved (Fig. 396) or straight iris-scissors; a metal spatula and flexible probe (Fig. 397); a blunt hook (Tyrrell's) (Fig. 398).

EXECUTION OF THE OPERATION.

1. Opening of the Anterior Chamber.—Suppose that the surgeon has to perform an upward iridectomy, the most frequent case. The patient is reclining on the operating-chair near a window or an Argand gas-lamp. An assistant throws light on the eye with a hand-lens. The operator, standing behind the head of the patient, separates the eyelids with a wire speculum, steadies the eyeball with the fixing-forceps, which he holds in his right hand, the thumb near the button of the catch, the second and third fingers on the other branch of the forceps opposite the catch. With the lance-shaped knife, which he holds in the same way as the forceps, he makes an incision in the upper part of the cornea at or near its transparent margin (the limbus).

The point of the lance, applied at a point directly opposite to the implantation of the forceps, is thrust through the cornea, at first somewhat perpendicularly, then, when it has entered the anterior chamber, which is recognized by the bright luster the blade assumes, it is pushed forward in a direction parallel to the plane of the iris as deeply as the intended size of the incision requires. Now it is withdrawn slowly, advancing the point toward the cornea as the aqueous escapes. This maneuver should be executed with a steady hand, so that the blade of the knife advances as if moved by machinery, and avoids injuring the iris and the lens-capsule on the one hand or the cornea on the other. Wounding the capsule would produce cataract, and grating the posterior surface of the cornea mostly leaves an indelible streak.

It is necessary that the tip of the knife be sharp and flexible, otherwise we may have difficulty in pushing it through the tough lamellæ of the cornea. Afraid of wounding the iris, we have a tendency to lower the handle of the knife; the tip, if flexible, becomes curved, with the concavity toward the iris, and can only with undue force be moved forward.

2. Excision of the Iris.—The operator, entrusting the fixing-forceps to the hand of an assistant, takes a pair of scissors in the right and the iris-forceps in the left hand. He closes the forceps and introduces their branches into the anterior chamber as far as the pupillary edge of the iris. He opens the forceps, the iris passes between the branches; the operator closes the forceps again and draws the iris out of the wound (more or less

of it according as a larger or smaller portion is to be removed), and cuts it off close to the cornea, the blades of the scissors parallel to the wound, or, if he wants to make a small incision, at right angles to it. In most cases the cutting can be done with one stroke; in some we may cut in two or three successive strokes.

The iris-forceps should be delicate; the tips of the branches should close nicely and remain closed when the branches are pressed together. Some forceps close at the tip when only moderate pressure is applied, but under stronger pressure they close at a posterior point and diverge at the tip. This is a great fault, for the instrument, after having seized the iris, loses it again when the operator presses the branches more firmly together.

The tips of the branches should be carefully rounded off. They frequently have sharp edges, which make the points liable to engage in the tissue of the iris, drag it along, and produce irido-dialysis and hemorrhage. Hemorrhage may also be produced if, while drawing the iris out, we exert not a straightforward, meridional traction, but a lateral one, which causes dialysis and rupture of the large arterial circle of the iris.

3. Adjustment of the Lips of the Wound.—No foreign substance, in particular no iris-tissue, must be left in the wound. It disturbs the healing, and may cause, in consequence of the angular entanglement of the iris, very unpleasant irritative processes—cystoid scar, corneal fistula, glaucoma, suppurative iritis, irido-cyclitis, and sympathetic ophthalmia.

The adjustment of the lips of the wound can be made satisfactorily in most cases by passing a spatula over the wound, flat and at right angles to the line of the section, so that the columns of the coloboma are moved back into the anterior chamber. Should we fail to accomplish this by outward pressure, we must pass the spatula through the incision, push the stump of the iris back of the wound, and particularly stroke the iris out of the corners, so that the sphincter is clear in the anterior chamber at a good distance from the wound.

During and after the operation a few drops of a mild antiseptic may be dropped over the line of incision and the cornea, as the latter, owing to the action of the cocain, becomes dry.

4. Dressing.—Both eyes are covered with pieces of corrosive-sublimate gauze, upon which are placed pads of absorbent cotton, which are held in position by the classic binocular (double figure-of-eight bandage), and the patient is put to bed.

The *recovery* in the great majority of cases is without disturbance. The eye is inspected every twenty-four hours, but need not be opened each time, unless some irregularity takes place. The patient is discharged in from seven to fourteen days, which, of course, does not mean that he shall have his full liberty so early.

Different Methods of Performing Iridectomy called for by Special Morbid Conditions.—(a) *Optical pupils* should be small. The incision is situated 2 mm. from the limbus in the clear cornea, and is 3 to 4 mm. in length; the iris is seized with a Mathieu forceps (Fig. 395) or a blunt hook (Fig. 398), and only the central portion excised. The coloboma should be situated where the optical conditions of the cornea as to curvature and clearness are best. If we have the choice, the situation nasally and a little downward gives the best sight.

(b) The *glaucoma pupil* should be large and peripheric, 1 mm. at least behind the limbus. In acute glaucoma with high tension cocain-anesthesia is mostly insufficient and perilous; because the diffusion-currents being directed peripherally, prevent the cocain from penetrating into the eye sufficiently to produce much effect. If the cornea be made tolerably insensible by it, the iris is not affected at all. The patient does not feel the corneal incision very much, but as soon as the forceps touch the sensitive iris he is apt to give a sudden jerk with his head, which may drive the tip of the iris-forceps into the lens. General anesthesia is to be preferred in these cases.

If one iridectomy in glaucoma gives only temporary relief, a subsequent one is better than a sclerotomy (compare with page 570).

Glaucoma occurs in about 1 per cent. after extraction of primary or discission of secondary cataract. If instillations of a myotic—eserin 1 per cent. solution or pilocarpin 2 per cent.—do not cure the attack, an iridectomy is sure to succeed (probably also a paracentesis of the anterior chamber). The

iris in such cases, as in all aphakial eyes, frequently escaping the ordinary forceps, should be seized with Mathieu's or other forceps the teeth of which are at the lower surface near the tip, not straight at the tip. If even these (capsule) forceps fail, a blunt hook, passed into the pupil, will grasp the pupillary portion of the iris and draw it out of the anterior chamber, where it can be abscised.

II. Other operations performed on the iris are—

1. Iridotomy is practised when, after a cataract operation, the pupil is closed and drawn toward the scar left by the wound.

The so-called pince-ciseaux of De Wecker (Fig. 399), a kind of cutting forceps, are introduced into the anterior chamber through a small corneal incision. The sharp-pointed branch is thrust through the iris, the other remains in the anterior chamber,

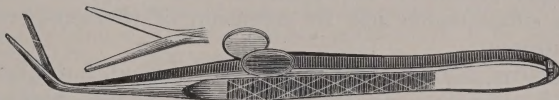


FIG. 399.—De Wecker's pince-ciseaux.

and in this way one or two incisions are made through the iris and pseudo-membranes that may be adherent to it. If successful, an artificial pupil can be obtained.

The author's personal experience is not sufficient to pass judgment on the value of this operation. After several trials, which were not very satisfactory, he has returned to—

2. Irido-cystectomy in such cases, which have become very rare in his practice.

An incision is made with a Beer's cataract-knife (Fig. 400) through the cornea, iris, and the adherent thickened lens capsule; next a Tyrrell's hook, or one branch of a pair of capsule-forceps (Mathieu's, Fig. 395) is passed into the opening in the iris; the

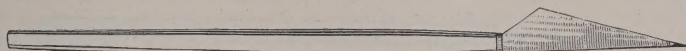


FIG. 400.—Beer's cataract-knife.

edge of the iris is seized, drawn out of the wound, and cut off close to the cornea. The results of this procedure have in general proved successful.

3. *Corelysis* (*synechiotomy*), the detachment of posterior (Streatfeild) or anterior (Lang) synechiæ, has not been found sufficiently beneficial to be regarded as a standard operation.

4. The *iridencleisis* of earlier surgeons and the *iridodesis* of George Critchett, by which pieces of the iris were healed into a corneal wound, and thus the iris drawn away from a central opacity, have been abandoned in favor of the easier and less hazardous iridectomy.

OPERATIONS ON THE CRYSTALLINE BODY.

The crystalline body, consisting of the lens and its capsule, gives occasion for two kinds of operative procedures which, as to delicacy and precision of execution and to brilliancy of results, are excelled by no other department of surgery.

A. **Operations on the Lens.**—When the lens becomes opaque in some way or other, either partially or totally, it intercepts the rays of light on their way through the pupil. If the lens is removed from behind the pupil,

the object of the surgeon is obtained. This can be done by displacement, by extraction, or by solution.

I. Displacement at the present time is only exceptionally practised—namely, for certain forms of shrunken or secondary cataract. It is described by Celsus, and was used long before him. It was practised in two ways—(a) by *depression* (keratonyxis). A broad needle was introduced through the lower part of the cornea into the upper part of the pupil, where by the raising of the handle it dislocated the lens into the lower part of the vitreous. (b) by *reclination* (couching, scleronyxis). The needle was introduced through the sclerotic and lateral part of the lens into the upper part of the pupillary area, from where, by a curvilinear movement, it turned the lens back and down into the vitreous.

The immediate results of displacement were often brilliant, but in most cases sight was subsequently lost by ascension of the lens, or by irido-choroiditis and glaucoma.

II. Extraction also seems to be an old method, but has been systematically practised only since the French surgeon Jaques Daviel in 1845 re-discovered it. It soon obtained favor, and for the last forty years has been the chief operation for cataract.

The following instruments are required: A wire speculum (see Fig. 390); fixing-forceps (Fig. 391), as for iridectomy; a narrow (v. Graefe, Fig. 393) or a triangular (Beer, Fig. 400) knife, with a firm, non-flexible point, which, like the cutting edge, is of the utmost sharpness; a cystotome, the shaft of which may be straight or bent at an obtuse angle, in which case two are necessary—one for the right, the other for the left, eye (Fig. 401), and the point of which, with its short cutting edge very fine and sharp, is to be cautiously handled in cleansing and sterilizing; a Daviel spoon, flexible (Fig. 403); a blunt (olive-tipped) flexible probe (Fig. 397); a curved, flexible, and slightly grooved spatula (Fig. 397), and a wire loop, curved like a spoon (Fig. 404).



FIG. 401.—Right and left cystotomes.

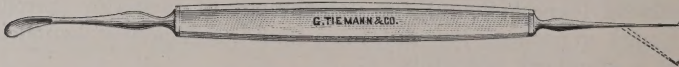


FIG. 402.—Cystotome and spoon.



FIG. 403.—Daviel's spoon.

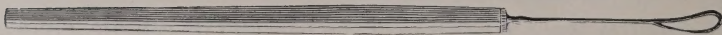


FIG. 404.—Wire loop curved like a spoon.

EXECUTION OF THE OPERATION.

First Step.—The Corneal Section.—The eye is cocainized. The operator, standing behind the patient, inserts the teeth of the fixing-forceps firmly into the episcleral tissue, and makes the corneal incision with a narrow Graefe knife held between the thumb and

the index and middle fingers of the other hand. We suppose we have to extract, by a superior section, a hard, mature, senile cataract, the anterior chamber being of normal depth. The knife pierces the cornea (*puncture*) in its transparent margin (*limbus*) slightly above the horizontal meridian, passes straight through the anterior chamber, and emerges (*counter-puncture*) on the other side at a point corresponding to the puncture. The section is continued by advancing the knife its whole length, and at the same time cutting upward without changing its direction, parallel and close to the iris, until it emerges at the upper end of the vertical meridian, where a small conjunctival flap is formed.

Second Step.—The Opening of the Capsule.—The cystotome is introduced, with its point backward, gently into the anterior chamber as far as the pupil; then its tip is pushed under the upper part of the iris, turned backward, and drawn across the capsule of the lens, so as to incise it 1 or 2 mm. below the equator, concentrically with the corneal margin. This maneuver requires some judgment in order to be sure that the capsule is opened without displacing the lens or rupturing its suspensory ligament, which would favor escape of vitreous during the operation and prolapse of iris later.

Third Step.—Expulsion of the Lens.—The speculum is removed; the operator takes the wire loop in one hand, and Daviel's spoon in the other. The patient looks steadily down; the convex surface of the spoon is applied to the lower portion of the cornea and pressed gently and steadily toward the *centre of the eyeball*, which causes the wound to gape widely and the lens to slip out gradually. When the greatest diameter of the lens has passed out of the wound the lower part is followed up with the spoon, so that the whole cataract is expelled. If during the expulsion the pupil does not dilate well and the upper part of the iris is pushed out bulgingly, the operator enlarges the pupil by pressing the bulging part of the iris backward with the wire loop.

Fourth Step.—Cleansing of the Wound.—During the operation and cleansing of the wound it is desirable to instil a few drops of an antiseptic solution, which will keep the eye wet and wash small particles away. Remnants of lens should be driven out by pressing with the finger the edge of the lower lid upward over the cornea. Neither the upper nor the lower lid should touch the open wound. Pieces of cataract lying between the lips of the wound must be removed with a well-sterilized spatula. Also small particles of lens lying still in the anterior chamber can be stroked out with the spatula.

If the iris does not return into its normal position spontaneously or by gently pressing a few times the lower lid with the finger on the lower margin of the cornea, the tip of a blunt probe has to be introduced from the side into the anterior chamber and passed onward along the iris-angle beyond the vertical meridian, in order to disengage the iris from the sinus of the anterior chamber, where it is crowded, and stroke it toward the center of the pupil. If this maneuver should not succeed or the iris should show a tendency to become displaced again, it is best to excise a small portion of it, and with a probe carefully push the corners of the defect out of the wound back into the chamber. Care should also be taken to stroke the conjunctival flap out of the wound.

Fifth Step.—Dressing of the Wound.—When the patient is put to bed the wound is inspected once more, and, if everything is satisfactory, both eyes are bandaged. A piece of sterilized gauze is put wet on each eye; upon it is placed a thin pad of absorbent cotton, the whole held in position by a roller bandage or strips of isinglass plaster.

The patient should lie quietly on his back as long as he feels comfortable; otherwise he may lie on the side of the non-operated eye. It is advisable to give an anodyne to the majority of patients soon after the operation.

Modification of the Operative Procedure.—The *corneal section* is placed *more or less in the opaque border* of the anterior chamber. This favors prolapse of iris and vitreous, as well as inflammations of the ciliary body.

The section is placed *within the transparent cornea*. This, by closing less accurately, tends to adhesions of the iris to the scar, especially at the corners of the wound, and is more liable to *primary* and *secondary* infection.

The section is made *downward*. This section is less protected by the lids, and optically at a disadvantage if an iridectomy has to be made.

The *opening of the capsule* is made with a cystotome or a hook, *extensively and in different directions*. In this way the capsule is torn, not incised. It has the advantage that in a certain number of cases the shreds of the capsule are drawn to the periphery and leave a sufficiently clear pupil, but the laceration and promiscuous opening often cause posterior synechiæ, and not rarely more or less obstruction of the pupil by inflammatory products which

it is difficult and risky to deal with. The opening of the capsule by a peripheral incision permits as easy and complete an expulsion of the lens as the central opening, and tends much less to iritis and capsular deposits. If later we wish to give the patient permanently the greatest possible sight his case admits of, we can do it by a simple discission of the wrinkled but not thickened capsule.

A piece of iris is excised either before (*preliminary iridectomy*, Mooren) or during the operation for cataract (*combined extraction*, von Graefe). This is indicated in all the cases—about 10 per cent.—in which the natural pupil does not admit of an easy exit of the lens or in which the protruded iris cannot be reduced or is likely to form a subsequent prolapse. That combined extraction is a safer operation than simple extraction is an assertion not confirmed by the writer's practice (in more than 1000 carefully recorded cases of each method). Simple extraction has the disadvantage that it is followed by prolapse of the iris in 5 to 10 per cent. of the cases. This can be remedied without much trouble and danger by excision of the prolapse within 24 hours after its occurrence. In all other respects simple extraction is superior to combined extraction.

The expulsion of the lens can also be accomplished as follows :

Cataracts may be extracted with the capsule. A. and H. Pagenstecher have tried this old operation as a general method, but had to limit it to hypermature cataracts where the capsule is thickened and the zonula Zinnii frail or ruptured. For such cases it is the best method.

In *soft and traumatic cataracts*, including those produced by operative interference—*e. g.* discission—in excessive myopia, zonular cataract, etc., the so-called linear extraction is appropriate.

With a lance-shaped knife the cornea is cut to the extent of 5 or 6 mm. near its border, and the capsule opened by piercing it with the lance, or it may be lacerated with a cystotome. The soft lens-substance is let out by backward pressure with the tip of the lance. If this is not sufficient, the posterior lip of the wound is pressed back by a wire loop, and as much of the cataract is coaxed out as will follow a moderate pressure. The reaction is mostly insignificant, but a subsequent capsulotomy is needed in most cases.

In *tremulous and dislocated cataracts*, or when *vitreous escapes before the lens*, the fixing-forceps and speculum should be removed immediately after the opening of the capsule and the *lens expelled by pressing with the edge of the lower lid toward the center of the globe*, while the upper lid is pressed gently on the sclerotic above, near the section. In this way the lens is moved into the wound, plugs the gap, and by a little additional pressure mostly comes out without, or with but little, loss of vitreous.

If, in exceptional cases, these external manipulations do not succeed, the lens has to be drawn out by a traction-instrument—a spoon, a curved wire loop (Fig. 404), or a sharp hook—introduced behind the lens, beyond the posterior pole. The introduction of traction-instruments should be avoided as much as possible.

For the *cleansing of the pupil* from remnants of cataract a Daviel's spoon has been used; the remnants also have been washed out with a syringe by injecting a very mild antiseptic lotion (*irrigation of the anterior chamber*). These procedures do not often succeed, nor are they free from danger. In expelling them by external manipulation care should, however, be taken lest by an unusual degree of pressure vitreous protrude.

Mistakes and Accidents during the Operation.—*Insufficiency of the corneal section* leads to stripping off of the cortex and bruising of the wound,

with deleterious consequences. Its presence is recognized if the lens presents in the wound, but does not advance. No forcible pressure should be used, but the section should be enlarged by a strong pair of strabismus-scissors (those of Stevens answer well).

If the knife on *its passage through the anterior chamber engages in the iris*, or if *the counter-puncture is not at the right place*, the knife should be drawn back and its direction corrected.

If the *iris falls over the knife* when the knife, after the counter-puncture, is moved upward, in many cases the iris can be re-dressed by turning the edge of the knife slightly forward; but if this fails to push the iris back, it is best to continue and to complete the section. The exsection of a small piece of iris does not much interfere with a good recovery.

Disturbances of the Healing Process.—Profuse intraocular *hemorrhage* during or after the operation is followed by the ruin of the eye, do what we may.

Prolapse of iris is treated in the manner already described (page 576).

Iritis is treated as usual—leeches, atropin, anodynes, etc.

Cyclitis with capsulitis, which mostly manifests itself in the second week by pain, marked, deep-seated circumcorneal injection, with a round, clear pupil and good sight, is commonly tedious and requires patient treatment for from three to six weeks. Then the sclera gets white, the vitreous clears up, the capsule is more or less opaque, but the vision is commonly not greatly damaged, and can be improved by a subsequent discission.

Irido-cyclitis, especially after combined extraction, is more deleterious. It lasts weeks, and sometimes months, damages sight greatly, leads to closure of the pupil, and dense pseudo-membranes behind the iris. We should not tire in treating such cases, for not infrequently, even if sight is reduced to perception of light, a cystectomy will restore useful vision.

Irido-cyclitis ruins, in rare cases, the other eye by sympathetic ophthalmia.

Suppuration may occur in the *cornea*, the *iris*, and the *vitreous*. In almost all cases it destroys the eye by extension to the deeper tunics—*panophthalmitis*.

In some cases a corneal suppuration is limited to the lips of the wound and the adjacent parts. The result is partial preservation of the cornea, indrawn scar, and closure of the pupil. If the eyeball is not soft and the light-perception good, an iridectomy may restore a moderate degree of vision.

Whether a beginning suppuration of the flap will be limited or progress to total destruction of the cornea seems to depend more on the nature of the individual case than on the medication employed. The author has not found that galvano-cautery or any other means has a controlling, or even favorable, influence on the morbid process. Of the many modes of treatment recommended and praised, the best seems to be to open the wound and establish drainage of the anterior chamber by reopening the wound with a spatula once every day or oftener. Eyes with *ring abscess* and *panophthalmitis* are beyond rescue. Our endeavor should be to relieve the atrocious pain and establish a safe and non-irritable stump suitable for wearing an artificial eye. This is best accomplished by poulticing and incisions giving free vent to the pus.

The *result* of cataract extraction is restoration of useful sight in about 95 per cent. of the uncomplicated cases, perception of light in 3 per cent., total blindness in 2 per cent.

III. Ripening Operations for Immature Cataract.—A cataract may be mature—*i. e.* opaque in all its parts—and yet not in the best condition for extraction. This is the case when the lens is swollen by imbibition, which, through the shallowness of the anterior chamber, renders it difficult to pass the knife through the aqueous humor without injuring the iris, and to make the counter-puncture at the right place. Usually in from three to six months the imbibed liquid will be absorbed, the lens will be smaller and compact, and the anterior chamber of normal depth. This is the time for the extraction.

On the other hand, cataracts may be immature and yet can be extracted easily and cleanly. This is the case when the nucleus is opaque and the transparent cortex pervaded by gray lines situated in the layers next to the capsule; or when the cortex is transparent, but the nucleus amber-colored, and the patient has reached the age of sixty years. Frequently enough in cataracts not coming under the above categories the natural ripening is so slow as to cause the greatest discomfort and render the patients unfit for work. Under these circumstances artificial ripening has been resorted to in different ways:

1. Opening of the capsule with a needle, as in discission of soft cataract (see later on). This is the oldest and perhaps most efficient method, yet it has the disadvantage of ripening the anterior cortex only, so that after the extraction we are surprised by finding a considerable quantity of lens-matter left behind. This may not be the case if, as Schweigger recommends, the discission goes deeper into the lens-substance.

2. Iridectomy and trituration of the lens by rubbing a blunt instrument over the cornea (Förster).

3. Paracentesis of the cornea and trituration of the lens with a blunt probe (Born), spatula (Sasso and Piscaldi), or trowel (B. Bettman) introduced into the anterior chamber.

4. Paracentesis of the cornea and trituration of the lens through the cornea (T. R. Pooley, J. A. White).

The writer has used some of these methods, with little satisfaction. He advises his patients to wait till Nature ripens their cataracts—which she always does harmlessly—and if they cannot wait, he in most cases would rather remove an unripe cataract (provided the anterior chamber is not shallow), and deal with the remnants later, than subject the patients to preliminary ripening procedures, which are unreliable and require operations for secondary cataract not less frequently than where immature cataracts are removed.

IV. Discission of the lens is indicated—1. In all cataracts of young people up to fifteen years of age.

2. In soft cataracts of adults as long as there is no hard nucleus. In these the discission has frequently to be followed by extraction on account of the advent of glaucoma.

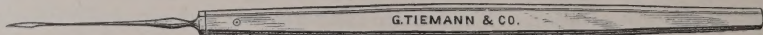


FIG. 405.—Knife-needle.

3. In transparent lenses in younger people suffering from excessive myopia, 16 D. and over.

Instruments.—Fixing-forceps, a discission-needle, or small knife-needle (Fig. 405).

The execution of discission varies under different conditions.

For division of *soft, zonular, and partial cataracts* the operator chooses a short knife-needle, thrusts it through the cornea midway between center and circumference, and through the capsule, 2 mm. beyond its center; draws it back to make a horizontal incision of 4 mm. through the capsule; then he rotates the instrument 90°, transfixes the capsule 2 mm. above the horizontal incision and cuts down into the horizontal incision; now he turns the needle 180°, transfixes the capsule 2 mm. below the horizontal incision, and cuts upward into the latter. In this way the capsule is opened by a crucial incision of 4 mm. in either direction. The cuts should be superficial, lest the lens by too rapid imbibition swell too much and cause glaucoma. Yet a small particle of lens-substance may be pushed with the needle into the anterior chamber, for small and superficial openings of the capsule may close again and have no effect. In most cases the discission has to be repeated several times, and the last time the posterior capsule should be divided, otherwise it will by wrinkling and dotting obstruct the pupil subsequently.

For the removal of the transparent lens in cases of *excessive myopia* the same precautions and repeated operations have been made, but Dr. Fukala, the chief advocate of the "operative treatment of myopia," now recommends breaking up the lens in the first operation by extensive discission, soon to be followed by extraction. The writer has no personal experience in removing the transparent lens in myopia. The operation has been practised of late by a number of eminent European oculists, and, on the whole, favorably commented upon. It is like operating on zonular cataract, and said to have no influence on the fundus changes. Hemorrhage in the vitreous and detachment of the retina have been noticed after the operation. In a large number of cases the visual tests after the operation have discovered a remarkable increase of the sharpness of vision (see also page 224).

B. Operations on the Capsule, the so-called Secondary Cataract.—For secondary cataract many operative procedures have been recommended.

1. *Discission* is indicated for all obstructions of the pupil that can be cut with a small knife or a needle. It is rarely that the capsule, when partially or totally left in the eye, remains permanently clear; it wrinkles, dots, and thickens, diminishing the vision more and more. Discission should be done if the vision is less than $\frac{2}{30}$. The best time to do it is from six to twelve weeks after the extraction, when all irritation has passed and the capsule has not yet become thick and tough. It can be done, however, at any later period. For many years the writer has operated in the following way:

The eye is cocainized, the pupil dilated. An assistant throws the focal point of an intense pencil of light (Argand gas-burner, incandescent gas, or electric light; large hand lens) on the capsule, leaving half of the cornea, through which the operator looks, unilluminated. The operator has previously examined the eye with focal light and the ophthalmoscope to ascertain how much diminution of sight is attributable to the capsule. If he gets a clear image of the fundus, cystotomy is out of the question; further, he has to find out where the capsule is least tough in order to determine where and in which direction it should be split. The plan of the operation is the same as in discission of soft cataract (see above).

A straight knife-needle with a sharp point, a sharp cutting edge and a rounded back is used. The blade and shaft should be so proportioned that the shaft just fills the wound made by the blade. Sickie-shaped needles do not readily stab the delicate, elastic, and readily escaping pieces of capsule when the first incision has been made. Needles of so little width as here required cannot be made sharp if they have two cutting edges instead of one and a back, as on a knife. With a well-made knife-needle three incisions can be made without escape of aqueous humor or bruising of the edges of the puncture-canal in the cornea.

The capsule must be divided by two incisions (no tearing), T-shaped; sometimes three incisions, +, crucial. Bands offering resistance must be left alone; it suffices to clear the space beside them. The needle should not be entered more deeply into the

vitreous than is necessary to split the capsule. The incision should be effected by the simultaneous movement of a lever and a knife which is gradually withdrawn, the corneal puncture being the fulcrum. The handle of the knife-needle is to be held between the brawn of the thumb on one side and that of the index and ring fingers on the other, so that an axis rotation of 180° can be easily and securely made. If by some accident or other the splitting of the capsule has been insufficient, no harm is done by introducing the needle again, from another point of the cornea, in the same sitting or later on.

The reaction of this operation is mostly insignificant. The writer has done this operation seventeen or eighteen hundred times and never lost an eye by it, and rarely ever damaged one. Suppuration has never followed, but glaucoma occurred every now and then, in about 1 per cent. of the cases. It has always been cured by a myotic or an iridectomy. The results for sight have been most satisfactory, and the sharpness of sight, once acquired, was not lost again by a disease that was in causal connection with the operation, if exception is made of cases of subsequent glaucoma which were inaccessible to treatment. The patients should be warned not to let themselves be deluded by the absence of discomfort during the first days, but avoid exposure and over-exertion, and, should irritation occur, at once consult an oculist and have a myotic instilled or an iridectomy made if glaucoma be present. The cases are very rare, however.¹

2. *Cystectomy, iridectomy, iridotomy, or irido-cystectomy* should be done if the pupil is occupied by tough pseudo-membranes or closed altogether. The operations are described before (see pages 577-579).

3. In cases of tough capsules a *double-needle dilaceration* may be done. One needle is introduced with one hand through the nasal side of the cornea and thrust through the center of the lens, and held there; another is introduced with the other hand through the temporal side of the cornea, and thrust through the aperture in the capsule which the first needle has made. By approaching the handles to each other the points diverge, and tear a hole into the capsule without dragging on the ciliary processes. By this procedure we often succeed in making a permanently good opening in the capsule. It is not hazardous.

¹ Operations on the capsule for secondary cataract are dreaded by many experienced operators, who have lost eyes (which had obtained useful vision through extraction of primary cataract) by the severest inflammations, including suppuration and panophthalmitis. The reason why the writer thus far has escaped such sad experience probably is that he performs the extraction with a view to supplement it by a discission—namely, in such a way as to exclude, as much as is in his power, any reaction that may lead to the deposition of inflammatory products in the pupil. This object, he thinks, is obtained, more than by anything else, by the periphtric incision of the capsule, which is rarely followed by iritic processes. His statistics of many hundred cases show the average acuteness of sight to be $\frac{2}{3}$ before and $\frac{2}{3}$ after the secondary operation. The latter is done in about 70 per cent. of the cases, and consists nearly always in a discission. In less than 2 per cent. has he had occasion to make another operation for secondary cataract.

The after-treatment of cataract operations has been mentioned above in different places, the dressing on page 578, the operative treatment of prolapse of the iris on page 576. To prevent accidental injury, in particular iris-prolapse, various kinds of masks are in use. Some masks imply danger by themselves, all are more or less uncomfortable, and many patients of the author have preferred to have their hands tied. It is advisable to inspect the eye the day after the operation and remove an iris-prolapse, if there should be any, at once. The bandage may be removed from the non-operated eye on the third or fourth day, from the operated eye several days later. The patient may be kept in bed for five or six days, old people less, for fear of hypostatic pneumonia. Attacks of mania are combatted by hypodermic injections of hyoscin, gr. $\frac{1}{100}$ pro dosi.

OPERATIONS UPON THE EYE-MUSCLES.

By S. C. AYRES, M. D.,

OF CINCINNATI.

OPERATIONS upon the ocular muscles may be necessary for the relief of concomitant and paralytic strabismus, as well as for want of balance in opposing muscles where squint does not exist.

The surgical correction of strabismus includes tenotomy of one or more of the ocular muscles, or advancement combined with tenotomy. Partial and complete tenotomies are also performed to correct various types of heterophoria, and advancement may be employed for the same purpose. Finally, advancement preceded by tenotomy of the opposing muscle is utilized to relieve the faulty results of strabismus operations, or in certain cases to counteract the deviation produced by paralytic squint.

I. Complete Tenotomy.—(a) **Tenotomy of the Internus.**—The operation for convergent strabismus which has been very generally adopted is the one devised by v. Graefe. It is the easiest of all the operations, and has only one disadvantage, if it may properly be so called—namely, the necessity of a suture in the conjunctiva. It is performed in the following way :

After the conjunctiva is cocainized the lids are separated by a spring speculum, and an assistant seizes the conjunctiva close to the outer side of the cornea and rotates the eye directly outward in the axis of the commissure, in order to prevent the natural tendency of the patient to turn the eye upward. The operator grasps the conjunctiva with a pair of forceps directly over the tendinous insertion of the muscle, raises it, and makes an opening, either in a vertical or horizontal direction, large enough to admit the easy introduction of the hook. Next, the subconjunctival tissue is incised, so as to expose the tendon of the muscle, and the hook is passed beneath the tendon, care being exercised to secure the entire tendon. The muscle is severed close to its insertion in the sclera with two or three cuts of the scissors.

An examination should now be made with the hook, above and below, to determine whether the tendon has been entirely severed, and also to ascertain whether any offshoots remain which may limit the motion of the eye outward. If the patient is not anesthetized, this may be readily determined by directing him to forcibly rotate the eye outward. The patient should next be directed to "fix" an object near by—the point of a pencil or the tip of the finger. If convergence still remains, the effect of the operation may be increased by incising the capsule of Tenon. This should be done with care, and, after snipping the capsule above and below the severed tendon, adduction and abduction should be tested. If the effect is satisfactory, the conjunctival wound should be closed with one or two sutures, both eyes bandaged, and the patient required to remain within doors until the following day, when the bandage may be removed.

If too much effect has been produced, a suture should at once be inserted in the cut end of the muscle from within outward and brought out through the conjunctiva close to the cornea. It should be securely tied, and then a bandage applied, as above directed, until the following day, when the eye should be opened and allowed to take part in the visual act. The primary suture may be removed on the second day after the operation, but when a suture is introduced to counteract excessive effect it should remain for two or three days.

(b) **The subconjunctival operation**, commonly known as Critchett's operation, is done in the following way :

The eye having been cocaineized, the lids are separated by a spring speculum (it is supposed the internal rectus is to be operated upon), and an assistant firmly seizes with forceps the conjunctiva and subconjunctival tissue near the outer edge of the cornea to prevent rotation of the eye on its axis. The operator next raises the conjunctiva with a fine-toothed forceps over the lower border of the rectus muscle, and makes an opening sufficiently large to admit easy insertion of the scissors and hook. It is better to have this opening too large than too small. After the incision of the conjunctiva the subconjunctival tissue is divided by successive short snips with the scissors, and undermined in the direction of the caruncle, until an opening is made in the capsule sufficiently large to enable the operator easily to introduce the hook. The hook, held in the right hand, is inserted on the flat, its point in contact with the sclera, and is passed under the muscle and drawn toward the insertion of its tendon. Then the point is elevated until it raises the conjunctiva in a tent-like manner. The hook is now grasped by the left hand of the operator, the assistant removes the forceps, and the tendon is severed by a series of short snips until the lessening of resistance and the elevation of the hook under the conjunctiva indicate complete division of the tendon. Where the tendinous insertion is broad it may not be entirely taken up on the hook, and another attempt to secure it should be made. After the section has been performed the hook should be swept through the opening in order to catch any strands which may have escaped division. If a decided effect is desired, the opening in the capsule, above and below, may be enlarged.

The conjunctival wound does not need a suture to close it, and only a compress bandage for a day is necessary. It is more difficult to perform this operation than the one previously described, because the tendon cannot be seen, but only felt. Sometimes with an unruly patient the cutting is not smooth; occasionally the tendon slips off the hook. Straight scissors are better in this operation than curved, although the operator may use the kind he prefers.

(e) **Snellen's Method.**—Snellen makes a vertical incision in the conjunctiva directly over the middle of the tendon of the muscle. After the opening has been sufficiently enlarged and the tendon exposed he seizes it with a pair of forceps and makes an opening or buttonhole in it, through which he passes the hook and cuts the upper portion, and then the lower portion, of the tendon in succession, close to the sclerotic. The subsequent dressings are the same as after the Graefe operation. He claims that this method does not interfere with the capsule of Tenon or with the indirect insertion of the muscle in its connection with the capsule.

In order to increase the effect of a tenotomy, in certain cases Knapp inserts a suture through the superficial layers of the sclera at the outer side of the eye and passes it through the skin beyond the outer canthus, where it is tied and allowed to remain a few hours. If insufficient effect is found to exist the day after the operation, it can be remedied in some cases by again cocaineizing the eye and opening the wound, and passing the hook under the tendon and separating it from the sclera.

There is a marked difference in the size and strength of internal recti muscles. The hook can be readily pushed beneath most of them, but occasionally a tendon is found which is thick and broad, and apparently drawn very tightly over the sclerotic, and which presents an unusual amount of resistance. In such cases only the point of a hook can be inserted underneath the tendon, which must be severed by successive short snips. In these cases there is danger of perforating the sclerotic.

Choice of Operation.—It is probable that most of the tenotomies of the internal rectus are performed either by Graefe's or Critchett's method. The judgment and experience of the operator will be his guide in choosing the one best suited to each individual case. The writer prefers the subconjunctival operation.

(d) **Tenotomy of an Externus.**—This is accomplished in a manner identical with that described in connection with the internus. The external rectus is inserted farther from the cornea (7 to 8 mm.) than the internus, its insertion is not so broad, and it is more lax than the inner muscle. The effects of its division are not so marked as those seen after tenotomy of the

internus, and hence are often disappointing. Not infrequently it is necessary to tenotomize both externi simultaneously.

(e) **Gruening's Method.**—In absolute divergent strabismus Dr. Gruening tenotomizes both external recti at one sitting, as follows :

Where the divergence is not more than 2 mm. the tendons are divided at their insertion. Whenever the deviation measures more than 2 mm. the tendons are divided at a distance from their insertion, this distance corresponding to the degree of squint. When the deviation amounts to 5 mm. by the corneal reflex, both tendons are divided at that distance from the points of insertion. After closing the conjunctival wound a silk suture is passed through the conjunctiva over both interni muscles in a line with the horizontal meridian of the cornea, and tied over a pledget of cotton on the bridge of the nose. This position is maintained twenty-four hours.

(f) **Tenotomy of the Superior and the Inferior Rectus.**—In operating on the superior and the inferior rectus muscles the same precautions are required as in operations on the internal and external muscles. It is better to employ the open method by cutting down upon and exposing the insertion of the tendon.

II. Graduated or Partial Tenotomy.—Operations on the internal, external, and vertical muscles for esophoria, exophoria, and hyperphoria are made by partial or graduated tenotomies, as devised by Dr. Geo. T. Stevens. The tendon of the muscle is partially severed, and then a test of the effect produced is made and the operation continued until the desired result is obtained. Dr. Stevens operates as follows :

If the right internus is to be operated upon, the patient is directed to turn his eyes well to the right. The surgeon, with a pair of fine forceps (Fig. 406, *A, B*), takes a

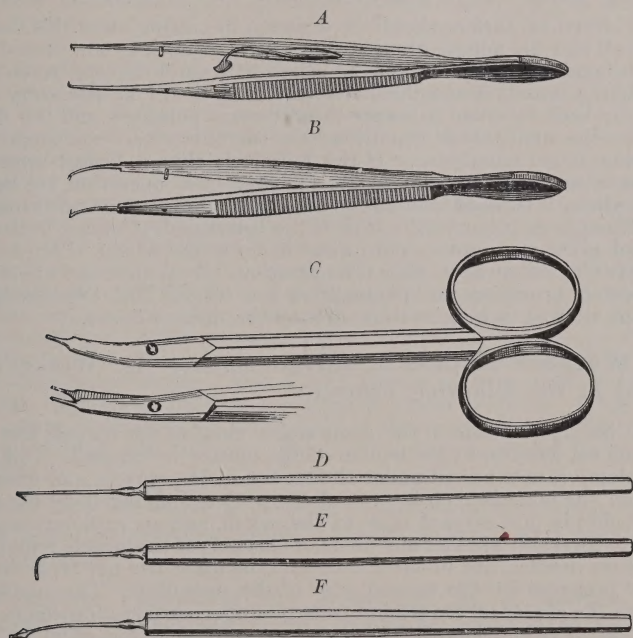


FIG. 406.—Instruments used in graduated tenotomy.

minute fold of the conjunctiva at the center of insertion of the tendon. Drawing this little fold of conjunctiva slightly away from the eyeball with the extreme point of the tenotomy-scissors (Fig. 406, *C*), the operator snips the fold transversely, so that an opening $\frac{1}{2}$ mm. in extent is made through the membrane. Now the forceps,

the points being closed, are pressed into the little opening and slightly backward, where the points are permitted to spring apart, after which they are again closed, this time holding a small fold of the tendon just behind the insertion. This being put upon the stretch, the scissors by little snips dissect the tendon from the eyeball between the layers of the capsule (which should remain intact) toward one border of the insertion. Then the tendon is cut toward the other border of its insertion. After this the tests for adduction and abduction are made, and further operative interference regulated according to the results. In like manner, the tendon of the external, superior, or inferior rectus may be partially divided.

This operation has received commendation and criticism, and it is open to both. It is suitable to cases where a very slight effect is desired. The fact that it has to be repeated several times is an argument against it, and in favor of a more pronounced effect which can be gained in one or two partial tenotomies.

III. Advancement or Readjustment and Resection.—In this operation the tendon of a rectus muscle is brought forward to a new attachment.

(a) **Advancement to Correct Faulty Strabismus Operations.**—Operations for advancement after squint operations present difficulties and complications not found in other cases. The conjunctiva over the incision is generally firmly cicatrized to the subconjunctival tissue and sclera. This may be due to the fact that the original incision was not closed by a suture and that the exposed scleral surface had granulated. Again, the insertion of the muscle is sometimes very thin and cord-like, and is attached to the sclera by a mere thread. The retraction of the muscle may have been very great, and one must search carefully for its new and abnormal insertion.

First, the cicatricial surface should be denuded by cutting away this tissue until the sclera is exposed and the muscle brought into view. A hook is now passed beneath the muscle, which is raised up until it can be seized with catch-forceps, when its insertion is severed. If the muscle is atrophied and cord-like, it will be necessary to insert the needles very far back in order to secure the necessary purchase, and the difficulties of passing the needles under these conditions are sometimes very considerable, owing to the cicatrization above mentioned. If the muscle is thin, a thread armed with three needles, as described elsewhere (de Wecker's advancement operation, see below), should be used; but where it is broad enough for the insertion of one thread through its upper and another through its lower border, this is the better plan to adopt, because it spreads the muscle and gives it a more secure attachment to the sclera. Both eyes should be bandaged for two or three days after the operation. As soon as the eye is firmly fixed in its new position, providing no inflammation has ensued, both eyes should be opened and the patient allowed to walk as usual around the ward or house.

(b) **De Wecker's Method of Advancement.**—De Wecker's operation is performed in the following manner:

A vertical incision is made in the conjunctiva close to the cornea, and the subconjunctival tissue cut away until the tendon of the muscle is exposed. One branch of a de Wecker's clamp is now passed under the tendon of the muscle, and when it is in the proper position the other branch is pressed down, thus holding it by the forceps (Fig. 407). The tendon is now severed close to the sclera, and an exploration is made with a small hook to ascertain whether any fibers or offshoots of the muscle remain. A thread armed with three needles, one in the middle and the other two not far from the ends of the suture, is prepared for the second step of the operation. The middle needle is passed through the center of the tendon from its under surface, and comes out through the conjunctiva. The location of this stitch is regulated by the effect to be produced, being inserted nearer the caruncle when more effect is desired. The two needles are then passed deeply under the conjunctiva, coming out in the vertical meridian of the eye at a distance of 4 mm. from the cornea, one above and the other below. The clamp-forceps are now removed, and, if the muscle is to be shortened, that portion of the muscle within the clamp is severed. The middle needle having been cut off and the others also removed, the two sutures are tied as follows: The operator and his assistant

each take one of the threads and simultaneously tighten them. When the desired position has been attained the knots are tied and the ends of the thread cut off. An over-correction is made, because after removal of the threads the tendon recedes from the original position.

If after two or three days there is an over-correction, the threads are removed, and,

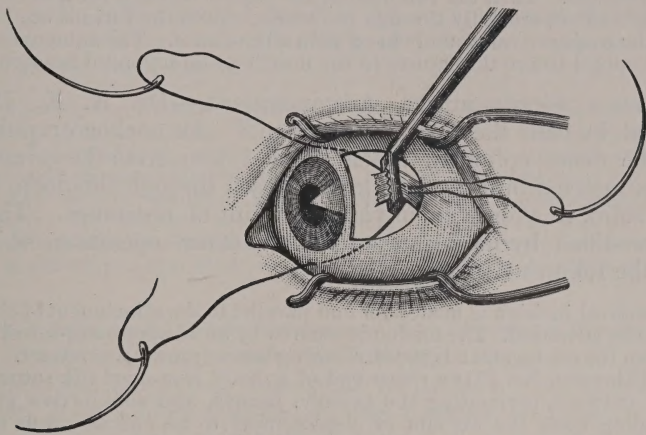


FIG. 407.—De Wecker's advancement.

after cocainizing the eye, a delicate hook is introduced into the wound and the attachments of the muscle loosened sufficiently to overcome the defect. If this is not necessary, the stitches are allowed to remain until the fifth or sixth day.

(c) *Noyes's Operation for Advancement.*—Dr. Noyes describes his operation as follows:

"Suppose the right rectus internus is to be advanced. The right rectus externus is first divided; then seize the insertion of the rectus internus with fixation-forceps, taking a deep bite to include all that can be lifted; sever the insertion freely, and cut down above and below into the conjunctiva to the extent of 10 to 15 mm.; have the forceps fast to the tissues by shutting the spring catch, lay it aside and then remove a vertical oval of conjunctiva in front of the insertion, leaving a strip 6 mm. wide next the cornea. Lift the muscle and pass a curved needle from within outward at its middle and as far back as the proposed effect will demand. With the needle in place cut off superfluous material in front of it, and then draw it through. The other two needles are introduced in succession and the tissues in front are cut off. This is done to avoid the danger of cutting off the sutures. We now have three threads through the muscle-fascia and conjunctiva. The needles at the other ends of the thread are next to be passed forward beneath the remaining conjunctival strip, taking hold of the outer layer of the sclera, so that the points emerge at the limbus corneæ. The middle thread is tightened first, and then the others in succession. The double knot is not tied until the threads have been successively tightened, and the eye is in a proper position. If there is much crumpling of tissue, it must be cut away, leaving the parts smooth. The stitches are allowed to remain from four to seven days. A bandage is applied for twenty-four or forty-eight hours."

The author does not think it necessary, except in rare cases, to cut away the conjunctiva as recommended above. He has found that it usually smooths down in a short time.

(d) *Schweigger's Operation of Resection of a Rectus Muscle.*—Schweigger incises the conjunctiva vertically, as well as the tissue of Tenon's capsule over the insertion of the muscle to be advanced. A hook, curved on the flat and with an olive point, is passed underneath the muscle and lifts it, exposing to view the entire tendon. A second hook is passed under the muscle in the opposite direction. One hook is pressed toward the corneal margin as far as the insertion of the tendon will permit, and the other one to that point where it is desired to insert the threads, thus exposing the muscle from 3 to 10 mm.

Two double-armed catgut threads are now prepared. One needle is passed under the upper edge of the muscle and pierces the same below the middle. The second is passed from the lower end and pierces the muscle above its middle. Each thread is then tied, thus including the entire muscle. The amount to be tied off is measured with a millimeter rule. That portion of the muscle between the catgut threads and its insertion is then resected. Then the two needles are passed through the insertion or stump of the muscle and superficially through the sclera. Both the threads are now tied and cut off and the conjunctival wound closed with silk sutures. The antagonistic muscle is always tenotomized before the sutures in the muscle to be advanced are tightened.

(e) **Prince's Single-suture Advancement.**—Dr. A. E. Prince has devised what he calls the "pulley operation." An anchor or pulley loop is made in the dense episcleral tissue about 1 mm. from the corneal margin. The sutures inserted into the muscle are passed through this loop, and, being fixed and solid, it affords an unyielding point of resistance. This method was later modified by its author to a single-suture operation, which is performed in the following manner:

A conjunctival incision is made over and parallel to the attachment of the tendon of the muscle to be advanced. The tendon is secured by an advancement-forceps (Fig. 408), separated from the sclera, and advanced, allowing the conjunctiva to retract. Two slender eye-needles (Tiemann No. 25) on either end of a No. 3 iron-dyed silk suture are passed from within outward, perforating the capsule, muscle, and conjunctiva at a variable point depending upon the amount of displacement to be effected, thus securing the middle portion of the muscle in a sling from which it can neither slip nor escape. With the exception of cases requiring a small amount of advancement of the muscle, as those in which the suture is used as a control to prevent an over-correction following a tenotomy, the portion of the tendon in the grasp of the forceps is excised about 2 mm. anterior to the sling. The sclera being now fixed, preferably with Critchett's short fixation-forceps, an unyielding anchorage in the form of a fibrous pulley is secured in

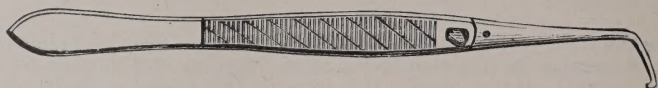


FIG. 408.—Prince's advancement-forceps.

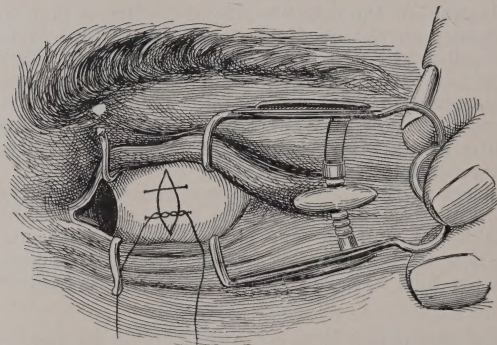


FIG. 409.—Prince's advancement.

line with the rectus by introducing either needle into the dense episcleral tissue 2 mm. from the sclero-corneal junction (Fig. 409).

Both ends of the suture are now brought together, forming the first portion of a surgical knot, and tightened to effect a slight over-correction. This suture is permitted to remain four days, unless it is desired to diminish the effect, which may be safely done after forty-eight hours by removing the suture and opening the wound with a small strabismus-hook. Tenotomy of the opposing muscle is made as in other operations.

This operation is better than the one first described by Dr. Prince, and gives very satisfactory results.

Dr. E. E. Holt has devised a somewhat similar operation.¹

(f) **Landolt's Operation for Advancement.**—Landolt is a firm believer "in the incomparable superiority of the advancement of the muscle over its setting back." He says: "There is more than one good method which leads to the same end. The essential point in all advancements consists in always bringing the muscle and its surrounding part as near the cornea as possible, and firmly fixing them there."

After exposing the muscle the surgeon inserts two threads, one through the upper and one through the lower border of the muscle, more or less behind its attachment according to the effect desired. After division of the tendon the threads are passed under the superior and inferior borders of the cornea, and, when necessary, as far as its vertical diameter. The threads are then knotted, bringing the tendon forward toward the corneal margin. An assistant turns the eyeball in the direction of the muscle to be advanced. When resection of the muscle is necessary, allowance for this is made before the muscle is cut off, and then that portion of the muscle still adherent to the tendon is removed.

Landolt's argument for advancement is that "it causes the eye to enter its muscular investment, from which the tenotomy causes it to escape." He does the operation in cases of strabismus in preference to tenotomy. Since advancement is so seldom followed by any reaction, he believes that it will come into more general use for strabismus.

The writer believes that this method of operating will be and should be more generally adopted. With the present aseptic precautions, it is no more dangerous than a simple tenotomy, although more difficult. The final cosmetic results will be more satisfactory. It better preserves the function of the muscle and prevents any advancement of the eye.

(g) **Stevens's Operation of Tendon-shortening or Advancement.**—Dr. Stevens's operation for advancement is as follows: The opening in the conjunctiva is the same as for tenotomy (page 589). Then, lifting the border of the conjunctiva nearest the cornea by the fine forceps, a little pocket is made by the points of the scissors or the lance-probe (Fig. 406, *D*), extending under the conjunctiva more or less toward the cornea in proportion to the greater or less effect which we propose to induce. The forceps seizes the central portion of the tendon, and it is dissected from the eyeball entirely or partially as the case may be. The fine tendon crochet (Fig. 406, *F'*) or the fixation-forceps with catch now seizes the tendon behind the section and draws it forward through the conjunctival opening, when one needle on a double-armed thread is passed through the central portion of it from $\frac{1}{2}$ to 1 mm. behind the cut extremity. The other needle is made to penetrate the conjunctiva at the extreme end of the pocket and the thread drawn through. Another thread is inserted in a similar manner a little to one side of the first, in order to allow between the two threads a little bridge of tissue. Now the surgeon draws upon the ends of the threads, forcing the cut end of the tendon into the little pocket, and fastens the threads by tying them across the little bridge. The sutures are removed on the third or fourth day.

Choice of an Operation.—The choice of an operation will depend much on the method one has practised or has seen practised. No one method has all the good qualities to recommend it, but, as all are intended to accomplish the same purpose, the surgeon can choose the one best suited to his own ideas. The method of resecting the muscle as performed by Schweigger, Noyes, and others produces excellent results. In this way the muscle is permanently shortened, and the cut end of the muscle attaches itself to the sclera at the point where the original insertion existed. It is not, however, always necessary to resect the muscle. In Noyes's operation the thread is passed underneath the conjunctiva of the severed muscle. It is probable that the Noyes operation is freer from the possibilities of danger than

¹ *Transactions of Am. Ophth. Society*, vol. iv. p. 123.

Schweigger's, owing to the deep insertion of the needle in the sclera in the latter. The former is the one the writer prefers, but he considers the two threads in the upper and lower edges of the muscle sufficient, without the use of the third or middle thread. In the limited space allowed it has been impossible to mention many of the operations devised by different surgeons. A choice had to be made from the many, and it has been done without any intended discourtesy to those omitted.

IV. Advancement of the Capsule; de Wecker's Method.—This operation is performed as follows:

A vertical incision as long as the corneal diameter is made through the conjunctiva over the tendon. The excision of a halfmoon-shaped piece of conjunctiva is only necessary in very high degree of deviation. An opening in the capsule is made, and through this the hook is inserted from above downward. The hook is passed completely under the tendon until its point is free on the opposite side. At the same time the capsule is incised above and below. Next, two double-armed threads are employed in the following way: One end of the thread is passed through the incision in the capsule from the inner surface, so that it pierces muscle, capsule, and conjunctiva. The point at which the muscle is pierced is regulated by the effect to be produced. The other end of the thread is carried through the incision under Tenon's capsule forward toward the corneal margin, through the superficial layers of the sclera, until it emerges from the conjunctiva at the vertical meridian of the eye, about 5 mm. from the cornea. There the two threads are tied simultaneously by the operator and his assistant. A surgical knot is first made, and when the eye is in position the double knot is completed. The conjunctiva is then closed by three sutures.

Knapp modifies this operation by the use of a third, middle suture passed through the equatorial flap of the conjunctiva, through the tendon (which was held up, drawn forward, and folded with a squint-hook), underneath the squint-hook, and through the episcleral tissue and the flap of conjunctiva near the cornea.

Advancement of the capsule is inferior to the advancement or resection operations described above. It leaves, for a while at least, an ugly knot or elevation under the conjunctiva, and its final results are not as certain and free from danger as other methods.

Accidents and Complications.—*Subconjunctival hemorrhage* is more or less abundant in every case of tenotomy or advancement, but it is readily absorbed and needs no treatment other than the use of hot fomentations.

Retrobulbar hemorrhage or *hemorrhage into Tenon's capsule* occurs occasionally. It is not likely to lead to serious results, but may vitiate the immediate effects of the operation. A compress-bandage should be applied over the eye, and on this iced compresses laid and changed frequently. Retrobulbar hemorrhage may be caused by vomiting during anesthesia.

Granulations occasionally spring from the incision in the conjunctiva. They are readily controlled by snipping them off with scissors close to the sclera or touching them with a crystal of copper sulphate or alum. Dr. Noyes reports a case where diphtheritic inflammation attacked the wound after a strabismus operation, and resulted in divergence.

Ulceration of the margin of the cornea from the end of the thread, which was cut off too long, occurred in the experience of the writer. It was promptly relieved by cutting off the thread. The breaking of a thread during an advancement operation is a very uncomfortable accident. It should be avoided by carefully testing the thread, which should be strong enough to stand the traction.

Panophthalmitis and *orbital inflammation* have been known to follow advancement operations, but the occurrence is extremely rare. *Perforation of the sclerotic* during the operation for strabismus occurs occasionally, even

in the hands of the most skilful operators. Cases are reported by Drs. Hasket, Derby, Knapp, E. Williams, and others. Panophthalmitis has followed this accident.

Instruments and dressings for an ordinary tenotomy of one of the recti muscles are—a spring speculum, two pairs of fixation-forceps (Fig. 410), two strabismus-hooks (Fig. 411), the one smaller than the other, two pairs of scissors, one curved (Fig. 412) and one straight (Fig. 413), a needle-holder (Fig. 414), and two or three needles threaded with fine black silk which



FIG. 410.—Fixation-forceps.



FIG. 411.—Strabismus-hooks.

has been waxed, absorbent cotton sponges, and dry absorbent cotton, fine gauze bandages, and a compress.

As the cornea becomes dry during exposure from the influence of cocain,

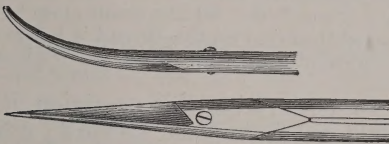


FIG. 412.—Curved scissors.



FIG. 413.—Strabismus-scissors.

it is well to have a dropper and some sterilized water in a glass dish close by, so that the cornea can be moistened in case it is necessary.

For advancement operations, in addition to the above, it is necessary to

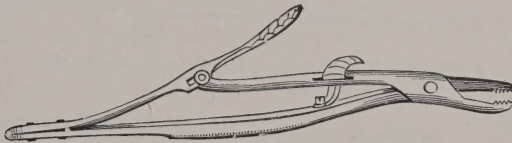


FIG. 414.—Needle-holder.

have long black silk thread or catgut sutures, armed with two or three needles, as described in the various methods devised by different operators.

Local anesthesia by cocain is much more desirable than general anesthesia, for the reason that the effects can be at once tested and any under- or over-correction remedied; but in children it may be necessary to administer an anesthetic. It is especially desirable to operate for advancement under cocain, for we want the aid of the patient to determine the effect produced. Eucain is recommended by Silex in squint operations.

OPERATIONS UPON THE LACHRYMAL APPARATUS.

By SAMUEL THEOBALD, M. D.,

OF BALTIMORE, MD.

Removal of the Lachrymal Gland.—This may be accomplished by either of two procedures :

The gland may be exposed by an incision through the integument of the upper lid parallel with the orbital margin, drawn out by means of a tenaculum and, with a knife or scissors, separated from its attachments. The objection to this method is that it involves a more or less complete division of the levator palpebræ superioris muscle, which may result in the production of ptosis.

The other, and probably better, plan, suggested by Velpeau, is to divide the external canthus, evert the upper lid, and cut down upon the gland from the superior conjunctival cul-de-sac. This method does not endanger the integrity of the levator muscle, and leaves a less conspicuous scar than the first-described procedure.

Bowman's Operation for Fistula of the Lachrymal Gland.—The purpose of this operation is to convert an external, cutaneous fistula into one opening into the conjunctival sac, and hence causing little or no annoyance.

A threaded needle is passed a short distance into the fistula, and is then made to transfix the lid, being brought out upon its conjunctival surface. A second needle, upon the other end of the thread, is next passed through the lid at a point close to the orifice of the fistula. The two ends are then tied tightly, and the thread is left to cut its way out. To promote the closure of the external fistula its edges are freshened.

Division of the Canaliculus.—In performing this operation it is important that the edge of the knife should not be inclined forward ; otherwise a slight perceptible deformity will result, and, besides, the position of the divided canaliculus will not be the most favorable for carrying off the tears. Weber's beak-pointed canaliculus-knife (Fig. 415), or the modification of it shown in Fig. 416, is usually employed.



FIG. 415.—Weber's beak-pointed canaliculus-knife.

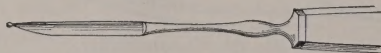


FIG. 416.—Probe-pointed, straight canaliculus-knife.

The operator should stand behind the patient, letting the patient's head (covered with a napkin) rest against his chest, the left hand being used for the left eye and the right hand for the right eye. The lid being kept upon the stretch with the thumb of the opposite hand, the probed tip of the canaliculus-knife is introduced vertically into the punctum (which, together with the canaliculus, should have been dilated previously by the passage of one or two of the smallest-sized probes), and then, the direction of the knife having been changed, it is passed horizontally along the canaliculus until its progress is arrested by the inner wall of the lachrymal sac (Fig. 417). This point having

been reached, and the edge of the knife being directed upward or upward and slightly backward, the lid being kept still on the stretch, the canaliculus is divided by simply elevating the handle of the knife. If the operation is done as a preliminary step to the introduction of lachrymal probes, the canaliculus should be divided well up to its juncture with the sac; but if done for some other purpose, such as eversion of the punctum or stricture of the canaliculus, it may not be necessary to carry the division quite to this point.

The edges of the divided canaliculus usually show for several days a disposition to grow together, and to overcome this they must be separated every day or every other day by the passage of a greased probe. A few instillations of cocain render the operation of division of the canaliculus almost painless.

The foregoing description applies especially to division of the lower canaliculus; but the upper canaliculus, which, in the writer's experience, seldom needs to be divided, may be operated upon by essentially the same procedure.

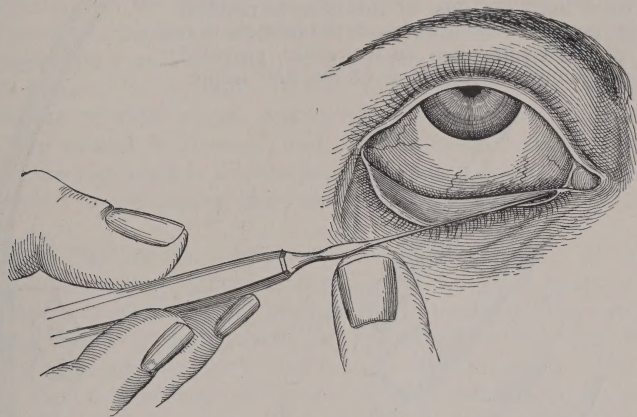


FIG. 417.—Passage of canaliculus-knife.

Excision of the Lachrymal Sac.—Owing to the delicate structure of the walls of the sac, this is not an operation easy of performance.

A vertical incision of sufficient length is made through the skin and the internal palpebral ligament down to the sac, which is then dissected out as carefully and completely as possible with a scalpel or a pair of blunt-pointed scissors. After this the cavity left by the removal of the sac and the upper part of the nasal duct are scraped with a sharp spoon, and, the wound having been cleansed with an antiseptic solution, the edges of the incision are closed accurately with stitches and a suitable aseptic dressing applied.

Destruction of the Lachrymal Sac by Caustic Agents, etc.—Destruction of the lachrymal sac by the actual cautery is an operation of classical origin, having been practised by the Romans nearly two thousand years since. In more recent times the obliteration of the sac has been effected by the use of caustic agents, such as nitrate of silver, chlorid of zinc, nitric acid, Vienna paste, caustic potash, etc., and still more recently by the thermo-cautery and the galvano-cautery. The merit claimed for this procedure (and also for excision of the sac) is that it not only relieves the patient of the dacryocystitis and its unpleasant consequences, but that in some cases it cures the epiphora through the inhibitory influence which it appears to exert upon the activity of the lachrymal gland.

The usual method of performing this operation is to make a free incision into the sac through the external integument and the palpebral ligament, and through this to introduce the caustic or the tip of the galvano- or thermo-cautery, a Manfredi's speculum being employed to protect the lips of the incision.

Introduction of Lachrymal Probes.—Small probes are sometimes passed through the undivided canaliculus (to overcome occlusion of the puncta, etc.), but division of the canaliculus always precedes the passage of probes for the cure of occlusion of the nasal duct. Cocain lessens, but does not entirely do away with, the pain. It should always be used, however, and the probe should be anointed with vaselin containing 10 : 100 of cocain.

The writer prefers to stand behind the patient, using the left hand for the left eye and the right hand for the right eye, as in division of the canaliculus, since the patient's head can be more easily steadied in this position. The probe is passed horizontally along the canaliculus, the lid being kept upon the stretch with the thumb of the opposite hand, until its point comes in contact with the inner wall of the lachrymal sac; it is then turned into a vertical position and passed slowly through the duct until the floor of the nose is reached (Fig. 418). No especial difficulty attends the introduction of the large probes commended by the writer, provided they are properly constructed. It is of the first impor-

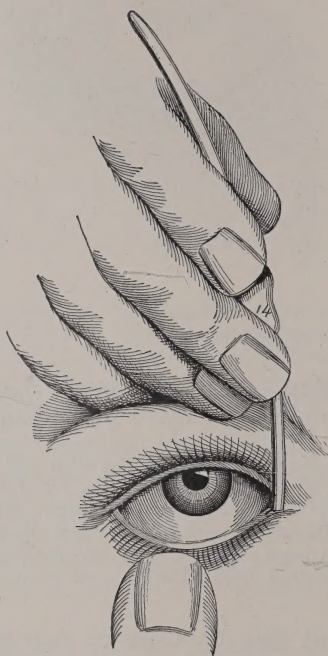


FIG. 418.—Introduction of lachrymal probe.

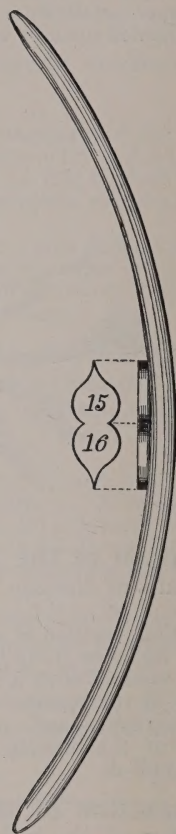


FIG. 419.—Theobald's lachrymal probe.

tance that their tips should not be too square and blunt. The accompanying illustration (Fig. 419), which represents the actual size of the largest probe of the series, Nos. 15 and 16, shows the proper shape of the ends as well as the curve which has been found most convenient.

OPERATIONS ON THE ORBIT.

By F. BULLER, M. D.,

OF MONTREAL, CANADA.

ALL operations on the orbital tissues should be performed in accordance with the strictest principles of antiseptic surgery. Even when septic conditions are present, they will in this way be favorably modified; if absent, the surgeon will himself be to blame if they follow his manipulations. It will not be sufficient to take these precautions merely during the operation. Every time the wound is dressed, and until healing has been fully accomplished, the same vigilance is imperative. The momentary use of an unclean probe may inflict more injury than the disease would have done if left to itself.

Abscess of the Orbit.—If an *abscess* has formed in the orbit, there should be no unnecessary delay in opening it. For this purpose a straight, narrow bistoury may be used, the incision being made at the point of greatest tenderness and swelling, or, if there be fluctuation, where this is most distinct, close to and parallel with the margin of the orbit. There need be no hesitation about thrusting the point deeply into the orbit, but only the external wound should be wide. An opening in the skin and oculo-orbital fascia half or three-quarters of an inch in length is desirable to relieve tension, unload engorged blood-vessels, evacuate pus if present, and facilitate keeping the wound open as long as may be necessary.

This is best done with a tent of borated gauze or lint inserted after thorough cleansing with some warm antiseptic solution, such as a 1 per cent. solution of pheno-salyl or any other that the surgeon may prefer. Compresses of sterilized gauze soaked in warm solution of sublimate 1 : 5000 or boric acid 3 per cent., frequently changed, are to be used till the inflammatory symptoms subside. The wound itself and the eye must be thoroughly cleansed at least two or three times daily. In severe cases of phlegmonous inflammation of the orbit early and free incision before the formation of pus, both above and below, conducted on the same principles, may be the means of saving the patient's vision or even his life.

Enucleation of the eyeball, eviscerations, and Mules's operation are described on pages 571–573.

Introduction of an Artificial Eye (*Prothesis Oculi*).—An *artificial eye* should be inserted as soon as the tissues are firmly healed and are able to bear the shell, which is usually from ten days to one month after the operation.

In order to insert an artificial eye the upper lid is seized between the fingers of the left hand and drawn gently down and out, and the larger end of the shell is inserted vertically beneath it, then brought to a horizontal direction, while at the same time the lower lid is pulled down, when the shell slips into place. In order to remove an artificial eye the head of a large pin is inserted beneath its lower margin, the lower lid being at the same time

depressed, while the eye is tipped upward and forward, when the pressure of the upper lid will force it out. Very soon patients become exceedingly expert in taking out and introducing artificial eyes, and do not require the aid of a pin in making the manipulation just described.

Until the tissues become accustomed to the artificial eye it should not be worn constantly, and should never be allowed to remain in the socket at night. If the enamel of the shell becomes rough, a new one should be substituted. If the socket or the stump upon which the eye rests becomes irritable or inflamed, the shell should be removed and the tissues treated with antiseptic lotions and mild astringents until they recover their healthy condition. It should be remembered that badly fitting artificial eyes have occasioned sympathetic inflammation.

Operations for Prothesis in Cases of Cicatricial Orbit.—Under certain circumstances, particularly after lime-burns and trachoma, contraction of the conjunctival sac and the formation of cicatricial bands may render it impossible for the patient to wear an artificial eye. A number of operative procedures have been devised to overcome these difficulties, but the results have been confessedly disappointing. Incisions made to admit the shell always close by cicatrization, and, if anything, increase the contraction. A few successes have followed transplantation of the conjunctiva of a rabbit, the skin of a frog, or Thiersch's graft. Operations based upon the principles of blepharoplasty (page 555) have also been tried.

Harlan's Operation.¹—In a case of cicatricial contraction of the cul-de-sac after enucleation Dr. Harlan proceeded as follows: "A heavy lead wire was inserted beneath the cicatricial bands and passed around the bottom of the cavity, and the ends brought together to form a ring. Way was made for the wire with a pair of fine sharp-pointed scissors curved on the flat, and it was inserted behind the lower band, brought out at the outer canthus, reintroduced, and passed in the same way above. The wire was worn for about two months, when it was cut down upon, its track found cicatrized, and the upper sulcus satisfactory. The lower sulcus was deepened by reintroduction of a wire. A thin leaden shell, formed so that its edges would rest where the wire had been, was afterward introduced and left in position constantly, except when the orbit was cleansed with boric-acid solution. After the lead shell had been worn for a few weeks, an artificial eye could be worn without difficulty."

Exenteration of the orbit is performed as follows:

The eyeball, if present, is to be removed in the ordinary way. Then the outer canthus is divided to the orbital margin, the lids drawn strongly upward and downward respectively, and the soft tissues back of them and the periosteum just within the orbital circumference divided with a scalpel. A strong pair of curved scissors is now used to peel off the entire periosteum to the apex of the cavity, where the whole mass is detached by means of a rounded raspatorium guided by the forefinger of the left hand. Bleeding from the ophthalmic artery, if considerable, may be checked by pressure with the finger, or by the use of Paquelin's cautery. When bleeding has ceased, the writer applies a thin layer of chlorid-of-zinc paste, spread on lint, to the shreds of tissue left in the spheno-maxillary fissure and apex of orbit, packs the cavity lightly with iodoform gauze, and applies a retention bandage. This dressing may be allowed to remain for several days.

If the malignant growth for which exenteration is proposed has involved the skin of the lids, these may require to be removed more or less widely, as well as the orbital structures. The gaping cavity thus produced may at the same operation be greatly diminished by sliding flaps of skin from the neighborhood in such a way as to partly conceal the deformity, or by Thiersch grafts.

Removal of Tumors from the Orbit.—The most suitable method of dealing with *orbital cysts* has already been mentioned (see page 531).

¹ *Trans. Amer. Ophthal. Soc.*, 1897, vol. viii. p. 63.

For *nevroid* or *erectile tumors electrolysis* gives the best results in young subjects, and may be repeated as often as necessary, every two or three weeks.

The most rapid effect is obtained by introducing two platinum needles, one for each pole. If the growth is large, the needle should be two or three inches in length. The skin is protected by coating the distal half of the needle with collodion. During the operation the needle attached to the positive pole is first introduced to the desired depth and held *in situ*. The negative needle is made to penetrate the tissues in several places around this, in each of which it is held in position for two or three minutes. There is some danger of injury to the optic nerve if the needles are passed deeply into the orbit.

General anesthesia is required, and, as reaction may be severe, it is best not to attempt too much during one sitting.

In adults these tumors may be partly, or, if encapsulated, completely, excised, and in some cases the *electric cautery* or *thermo-cautery* may with advantage supplement the knife and scissors.

Osteoid growths springing from or involving the roof of the orbit may be removed, but the operation is somewhat difficult and decidedly dangerous. A large percentage of such cases have died from consecutive intercranial disease—abscess or meningitis. Many of these, however, date from pre-antiseptic days. If the bony growth belongs to the inner or inferior walls, the danger is much less.

The growth must be exposed as freely as possible by suitable incisions of the soft parts covering it, including the periosteum, which must be carefully detached. Then the base of the growth is attacked with hammer and chisel, cutting the bone with tiny rapid strokes until the mass is detached.

The ivory-like masses which sometimes project into the orbit from adjacent cavities may be detached and "shelled out" by cutting completely through the normal bone immediately around them: when thus isolated they may be lifted out of the cavity with suitable forceps—a procedure which does not require much force in the absence of firm, deep attachments.

Tumors of the orbit which are extensively adherent to the globe or infiltrate the surrounding tissues cannot be removed without sacrificing the eyeball; for these the operation requires no special description.

In all other cases an attempt may be made to spare the eyeball. In any doubtful case the surgeon should have an understanding that he may sacrifice the eyeball if necessary.

Tumors of the optic nerve may be reached by a vertical wide incision of the conjunctiva over the inner side of the globe, detachment of the internal rectus tendon, which is to be secured and identified by a black silk thread, and held out of the way by an assistant. With the closed blades of curved scissors the tissues are to be separated down to, along, and around the growth quite to the apex of the orbit. With a strabismus-hook passed around the nerve at this point as a guide, use the scissors to cut the nerve close to the foramen. Then with small vulsellum-forceps bring the growth forward, reversing the globe, and detach close to the sclerotic. Bleeding must be arrested by pressure with the fingers or hot-water injections, and the parts irrigated with perchlorid solution 1:3000 before the tendon and conjunctiva are sutured into place.

Tumors outside the muscle-funnel are to be reached by free incision parallel to the orbital margin over the most accessible part of the tumor, doing all the deep dissection, if possible, with the closed scissors-blades or handle of the scalpel. Many growths may be successfully "dug out" in this way, with very little loss of blood or injury to the surrounding parts. All bleeding must be arrested before the wound is closed with fine silk sutures, and dressed antiseptically, with suitable provision for drainage.

Krönlein's Operation.—Tumors situated far back in the orbit may be exposed to view and removed without sacrificing the eyeball by a method devised by Krönlein, in the following manner: A crescentic incision is made around the outer circumference of the orbit. The periosteum is then divided at this part to a similar extent, and freely detached from the outer wall of the orbit as far as may be necessary. A temporary resection of a wedge-shaped portion of the orbital wall can then be made. The base of the wedge corresponds to the outer orbital margin, its apex to the anterior extremity of

the inferior orbital fissure. To accomplish this the zygomatic process of the frontal bone is chiselled through, as well as the intervening bone between this and the fissure, near its anterior extremity. In the same way the base of the orbital process of the malar bone is divided, and this second incision through the bone is continued backward to the fissure. The loosened portion of bone, together with the tissues attached to its external surface, may now be drawn toward the temple to such an extent that the orbit is freely exposed at its outer side, and a growth even at the apex is rendered quite accessible, and may be readily removed. After this has been accomplished the triangular flap of bone is replaced, the skin-wound united with sutures, and a suitable dressing applied.

It is said that recovery is complete in eight or ten days. The operation is neither difficult nor dangerous, and would seem to merit greater favor and have a wider range of application than it has yet received. It will be found useful in the extirpation of deeply-seated orbital tumors, as an exploratory operation in some doubtful cases of exophthalmos, and is an efficient means of relief in violent phlegmonous inflammation of the orbit. Should the exposed orbit be found in such a condition that complete exenteration is deemed advisable, this may be done at the same sitting.

Distention of the frontal sinus, if recent and of a purulent character, may be relieved by a free opening through its lower external (orbital) wall and subsequent drainage through the same aperture; but in chronic distention (mucocoele), the cavity or cavities having become much wider than in their normal state, simple incision will not suffice. Under these circumstances the surgeon proceeds as follows:

The orbital wall must be so freely removed that the little finger can be passed into the cavity after its thorough evacuation by syringing with some warm antiseptic solution. The little finger of the other hand or a strong probe is to be pushed up the nostril to a point where the finger in the sinus can be felt. Then an aperture of considerable size is to be made with a sharp scoop at this point, and a drainage-tube carried through from the orbit and worn until the discharge has ceased or the cavity has sufficiently contracted to justify its removal. Thorough cleansing at least twice daily must be practised for weeks or months to achieve this end.

This operation has the disadvantage of almost certainly injuring the pulley attachment of the superior oblique—an accident which may be avoided by making an opening with chisel or trephine in the forehead, a little to one side of the median line, and the counter-opening into the nose in the manner just described.

The opening in the forehead may with advantage be sufficiently enlarged to include the entire anterior wall of the sinus; but the disadvantage of this method is the somewhat unsightly resultant scar.

Orbital fistula, if found to extend into the frontal sinus, will heal when the sinus has been dealt with after one or other of the foregoing methods; that is, after the sinus has been effectually drained into the nose.

Should the fistula be found to lead into the ethmoidal cells, a free opening may be made down to these parts along the fistulous tract, and any accumulated secretion or other inflammatory debris removed by syringing and the gentle use of small curettes. A drainage-tube should then be inserted, and the cavity kept clean by daily syringing until healing takes place. This treatment may be required for several months. Gruening has effected cure of a fistula leading to the ethmoid cells by forcing, with a strong probe, an opening through the base into the nasal cavity, thus facilitating drainage through the nose.

APPENDIX.

THE METHODS FOR DETECTING COLOR-BLINDNESS, WITH SPECIAL REFERENCE TO THE EXAMINATION OF RAILROAD EMPLOYÉS.

BY J. ELLIS JENNINGS, M. D.,

OF ST. LOUIS, MO.

MANY PERSONS suppose that all that is required to test the color-sense of railroad employés is to display the flags and lanterns used as signals and demand the name of the color exposed.

The experienced observer knows, however, that many color-blind subjects can name colors correctly; hence, any test to be effectual must ascertain, not whether the employé can name colors correctly, but how he sees them, and whether he can safely be trusted to distinguish between the various signals on all occasions. We determine this, first, by making him pick out and place together those colors which appear to him to be the same, and second, by having him recognize colors at a distance under various degrees of illumination, thus simulating, as far as possible, the various atmospheric conditions under which railway signals may present themselves.

Holmgren's Method.—The set of worsteds consists of three large test-skeins: (1) *light pure green*; (2) *rose (purple)*; (3) *red*, and of about one hundred and fifty small skeins of the following colors: red, orange, yellow, yellow-green, pure green, blue-green, blue, violet, purple, pink, brown, gray, including several shades of each color and at least five gradations of each tint from the deepest to the lightest.

First Test.—The worsteds are placed in a confused heap on a large plane surface in a good light, and the *light pure-green* test-skein laid a little to one side. The candidate is now requested to pick out those skeins most resembling it in color and place them by the side of the sample. The examiner must explain that there are no two skeins exactly alike, and that an endeavor must be made to find something similar of a lighter or darker shade. The candidate is not to compare narrowly or to rummage much among the heap, but to select with his eyes, and to use his hands chiefly to change the position of the selected skeins.

A person with a *normal color-sense* will pick out the lighter and darker shades of green rapidly and without hesitation. He may, perhaps, include in his choice a few green skeins inclining to yellow or blue; but this is no evidence of color-blindness, but rather of a lack of practice with colors.

The person *completely color-blind*, whether to red or green, will select, with or without the greens, some confusion colors—grays, drabs, stone-colors, fawns, pinks, or yellows.

The person *incompletely color-blind*, or with a *feeble chromatic sense*, will add to the selection of greens one or more light fawns or grays; or he may pick out a skein, hesitate, add it to the greens, and then withdraw it, and so on. When confusion colors have been selected the examiner knows that the candidate is either completely or incompletely color-blind. In order to determine its nature and degree a second test is employed.

Second Test.—The worsteds are mixed again, and the large *rose* test-skein is laid to one side. The candidate is requested to pick out all the lighter and darker shades of this color; if color-blind he will always select deeper colors. Those subjects who by the first test were found to have a *feeble chromatic sense* will make no mistakes in this test. Those who are *incompletely color-blind* will match the rose with deeper purples. The *completely red-blind* candidate will select blue or violet, either with or without

purple. The *completely green-blind* subjects take green or gray or one alone, either with or without purple. The *violet-blind* subjects (rare) show a strong tendency to select blue in the first test, and red and orange, either with or without purple, in the second test. As this examination has decided the character and degree of the defect, it is not necessary to resort to the third test; but as the red skein used corresponds to the danger-signals, it may occasionally be of value in convincing the officials that the candidate is unfit for duty.

Third Test.—The sample for this test is a skein of *bright red*, to be used in the same way as the green and rose. The *red-blind* subjects select, besides the red, green and brown shades darker than the red. The *green-blind* subjects select green and brown shades lighter than the red. Only marked cases of color-blindness will show their defect with this test.

Thomson's Method.—This consists of two different sets of worsteds, which are kept apart in a double box. The *first set* consists of a large *green* test-skein and twenty small skeins, each marked with a bangle having a concealed number extending from one to twenty. Among these numbers the odd ones are different shades of green, while the even numbers are grays, light-browns, etc. The *second set* consists of a large *rose* test-skein and twenty small skeins, which are numbered from twenty-one to forty. Here the odd numbers are different shades of rose, while the ten even numbers consist of blues, greens, and grays.

In testing the worsteds are taken from the green part of the box and placed upon a table in a confused mass. The candidate is requested to select ten tints to match the large green skein. When this is done and the numbers recorded on a blank, the worsted is removed and the examiner proceeds with the second set.

Author's Method.—Realizing that any test which is limited to a small number of match and confusion skeins curtails the choice and makes the defect more difficult to discover, the author has endeavored to combine the good points of Holmgren's and Thomson's methods. The set consists of five large test-skeins: *light pure green*, *rose*, *red*, *blue*, and *yellow*, and eighty-four small skeins, each marked with a bangle having a concealed letter and number. The letter denotes the color, and the number (1 to 6) denotes the shade. For example, A 1 indicates the lightest shade of pure green; K 6, the darkest shade of brown.

The examination is conducted in a manner similar to the Holmgren method, with the addition of the blue and yellow tests. A record of one test is made before proceeding to the next. In matching the *blue* skein the color-blind person first takes the darkest shades of blue, and then adds the rose skeins, because he recognizes the blue in the mixture of red and blue. In matching the *yellow* he adds all the green skeins that have yellow in them.

Pseudo-isochromatic Plates of Stilling.—The remarkable facility with which the color-blind distinguish colors to which they are blind is due to an acute sensitiveness to differences in tint and intensity of light. In the pseudo-isochromatic plates Stilling seeks to deprive the color-blind of any aid in matching colors by selecting those which appear identical not only in tint, but also in intensity of light. On a colored surface of convenient size he painted a spot of the color mistaken for it; he then toned or modified this spot until the color-blind eye could not distinguish between the spot and the surface. Stilling then constructed ten plates, each plate containing four squares filled by small, irregular colored spots, among which other spots in a confusion color, made to conform to an Arabic figure, are placed. The test-plate is held in a good light and the candidate required to distinguish the tracings. An important feature of this test is that there is no inquiry as to color.

Lantern-test.—An ordinary switch lantern with a four-inch opening should be so arranged that pieces of colored glass can be placed in front of the light. The colors to be used are standard red, yellow, pure light-green, standard green, blue, and purple. The luminosity of the light can be varied by having at hand pieces of white (ground), ribbed, and different thicknesses of London-smoke glass. As red and green appear to the color-blind as one and the same color, only lighter or darker than the other, it is easy to deceive him by changing the luminosity of the light without altering its color. This can be done by diminishing the light or by placing pieces of ground or London-smoke glass before the colored light. The candidate should be seated at a distance of fifteen feet from the lantern, and, according to Dr. Edridge-Green, should be rejected—(1) if he calls the red green or the green red under any circumstances; (2) if he calls the white light under any circumstances red or green, or *vice versa*; (3) if he calls the red green, or white light black, under any circumstances.

Quantitative Estimation of the Color-sense.—The lantern may also be used to make a quantitative estimation of the color-sense by placing in front of the light a metallic slide with perforations ranging from one to twenty millimeters in diameter.

Having tested and recorded the average size of the opening required by the normal eye to distinguish each color at fifteen feet, the candidate is placed at this distance and is asked to name the colors. If he recognizes them through the one-millimeter opening, his color-sense is normal $= \frac{1}{1}$. If an opening of twenty millimeters is needed, his color-sense $= \frac{1}{20}$. If he fails to recognize the color through the largest opening, he is told to approach the light slowly, and if he sees it at three feet, his color-sense $= \frac{1}{100}$, etc.

Oliver's apparatus is designed to test the color-sense of employes upon the railway-grounds at a distance of 1000 feet. It consists of twenty-three shallow open wooden boxes, painted dead black, containing colored bunting placed upon a horizontal beam 15 feet from the ground. Arranged above the middle of these boxes is a large revolving box with five partitions for the test-colors. The pure-green test-color is displayed, and the candidate, employing one eye at a time, is asked to write upon a piece of paper the number of the color in the lower row (going from left to right) that to him is the nearest match to the upper color. This experiment is repeated with the other test-colors. If the apparatus is to be used at night, transparent colored glass is substituted for the colored bunting.

Chibret's Photometer.—An examination for color-blindness is not complete without making a test of the light-sense (see page 154). The most accurate instrument for this purpose is Chibret's photometer.

The candidate faces the window and looks with one eye into a tube, where he sees two equally bright disks. The eye-piece is now turned until he can detect a difference in the illumination of the two disks, when the *light-difference* is indicated on the scale. A normal eye recognizes the difference within five degrees. The *light-minimum* is measured by making one disk entirely dark, and then turning the eye-piece until he perceives the disk coming from the darkness. The scale should not register more than one or two degrees (see also page 152).

THE DISPOSITION OF THE COLOR-BLIND.

Having ascertained that the color-sense of an employé is defective, the surgeon must decide whether the defect is of such a nature as to warrant his discharge, or whether he can with safety be allowed to retain his position. If the person in question is an applicant for employment, even a slight defect of the color-sense should be sufficient ground for rejection. If, however, we have to deal with an old employé, one who, perhaps, has discharged his duties in a satisfactory manner, justice demands that his interests be studied so far as is consistent with safety. Every case of *complete red- or green-blindness* should be dismissed. Those who are *incompletely* color-blind, and in the first test merely confound gray with the sample color, may be retained if the *visual acuity* and *light-sense* are normal.

STANDARDS OF FORM AND COLOR-VISION REQUIRED IN RAILWAY SERVICE.

By A. G. THOMSON, M. D.,

OF PHILADELPHIA.

LAWs regulating the examination of railroad employes for form- and color-vision have been adopted in several States, but there is no official standard established by the United States Government for such examinations as exists in Continental countries. The State undertakings in this behalf have not been uniformly successful, as witness the experiment tried some years ago in Connecticut by which scientific experts were to be appointed by the governor and paid by the railroads. This undertaking proved a failure, as the railroad officers would not submit their employes to the scrutiny of State officials, who, by adopting their own standards, could practically discharge perhaps 15 per cent. of the railroad employes, disturb the discipline, and impair the organization of the roads.

As most of the large railroad lines run through several States, to save complications which may arise out of separate State legislation it is found more expedient for the cor-

porations to make their own rules and regulations for examination of their employés, using their own methods and appointing their own examiners.

It is found impracticable for corporations, owing to the large force of ophthalmic surgeons it would require, to study the refraction and make the examination as scientific as, from a medical point of view, is admittedly desirable. So it is, therefore, the endeavor of the railroads to devise and establish a general system of examination for protection of the public and its property that can be put in force by a division superintendent, acting through an intelligent assistant, under the general supervision of an ophthalmic surgeon. To this supervising surgeon all information collected could be transmitted, and he would thus be enabled to decide all doubtful cases and to protect the railroad from any danger arising from incapable employés, and at the same time to save good and faithful men from being discharged from the company's service without sufficient cause.

Such a system has been perfected by Dr. William Thomson, authorized by the Pennsylvania Railroad Company since 1880, and has been adopted by other roads from time to time, until it is protecting an aggregate total mileage to-day of over one hundred thousand miles. This system has been, as here indicated, subjected to the test of experience, and has proved very satisfactory.

Visual Acuity.—The standards of form-vision in Continental countries and also in this country vary from $\frac{20}{XX}$ in one or both eyes to $\frac{20}{XX}$ in one and $\frac{20}{L}$ in the other, in the first class—that is, for employés on the head end of an engine, while in Class II, representing the yard and train service, the range is anywhere from $\frac{20}{XX}$ in one to $\frac{20}{CC}$ in the other.

A railroad should require for its safety two standards for entrance into its service: The standard of Class I, representing engineers, firemen, and towermen, should require $\frac{20}{XX}$ in one eye, and not less than $\frac{20}{XL}$ in the other—vision taken separately without glasses.

Hyperopia over 2 D. should ensure rejection—astigmatism being eliminated. This can be readily ascertained by placing a trial frame containing 2 D. spherical-lens, before the patient, and if he has with these lenses full acuity of vision, the optical defect is demonstrated. This practical test saves many complications, as a man may enter the service as a young man with strong accommodation, and when he becomes a skilled engineer, at the presbyopic age, he will not have vision sufficient to reach the standard.

Periodic examinations should be made at intervals of five years, or after an injury which may in any way affect the vision, and also after serious illness and on promotion.

The standard of Class II, representing trainmen, conductors, brakemen, switchmen, and yardmen, should require $\frac{20}{XX}$ in one and not less than $\frac{20}{LXXX}$ in the other eye, with or without glasses, and the same rules regarding re-examination apply to them.

Old employés not reaching the proper standard of the class to which they belong on re-examination should be corrected and required to use glasses if they be permitted in that class or transferred to other duties.

Color-sense.—The color-sense is requisite to enable any employé to govern his actions by day or night by colored signals.

The standard should require three points:

I. Test with colored signal-flags.

II. Test by comparison of colored worsteds—Holmgren's, Thomson's, Williams's, or Oliver's.

III. Test with colored light.

I. *Test with Colored Flags.*—The man subjected to this test should recognize four flags, one of each color, red, white, green, and blue, and, at a distance of twenty feet, tell their color and meaning. A colored flag should also be given him to match with worsteds.

II. *Test by Comparison of Colored Worsteds, Matching their Colors without Telling their Names.*—Here one of the recognized tests should be used—Holmgren's or some modification of this test. Holmgren's test consists in testing the power of the person to match various colors which are conveniently used in the form of colored yarns. About one hundred and fifty tints are employed in confused mixture, and three test-colors—viz. light-green, rose-purple, and red—are placed in order before the person examined, who is directed to select similar colors from the mass. By this manner the examiner can judge whether selections are correct or not from the prompt or hesitating manner in which the selection is made.

Tests which are modifications of this, as, for example, Thomson's stick-test, are much simpler and more expedient for use on railroads.

III. *Test with Colored Light.*—The ordinary railway-lanterns of different colors may be used.

If the employé be found defective in his color-sense, he will undoubtedly be detected by these tests. He is then allowed to go before the ophthalmic expert for final examination, who may use any other confirming test he may choose.

It is to be remembered that this is not an official standard—simply the requirements to operate a railroad without danger to the public and destruction to property.

THE RÖNTGEN RAYS IN OPHTHALMIC SURGERY.

By WILLIAM M. SWEET, M. D.,
OF PHILADELPHIA.

WITH the development of improved methods of generating and employing the Röntgen rays speedy and accurate means have been furnished by which not only the presence of a metallic body in the eye may be determined, but also its exact position. The early employment of the new form of radiant energy in experiments on animals' eyes gave little promise of the successful application of the method in ophthalmic surgery until Charles H. Williams of Boston and C. F. Clark¹ of Columbus, Ohio, each reported a case of the removal of a piece of metal from the living eye which had been previously located by the rays. Shortly afterward Max J. Stern, at the Philadelphia Polyclinic, located metallic bodies in the vitreous in four cases, and demonstrated the possibility of obtaining shadows on the photographic plate of foreign bodies situated in any part of the eyeball or orbit.

Practical Application of Rays.—While numerous methods have been suggested and employed for determining the exact position of the body in the eye, the writer has

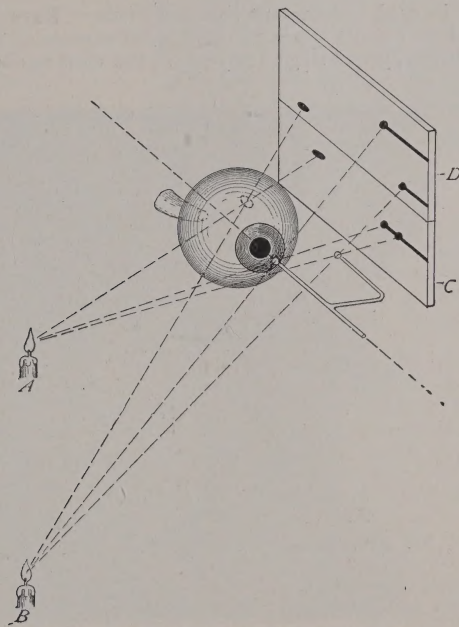


FIG. 420.—Principle of method of localization.

found the use of two metal indicators, one pointing to the center of the cornea and the other situated to the temporal side at a known distance from the first, to be simple in application and accurate in results. Two radiographs are made to give different rela-

¹ *Trans. Amer. Ophth. Soc.*, vol. vii. part iii.

tions of the shadows of the indicators and the body in the eyeball or orbit—one with the tube horizontal or nearly so with the plane of the indicators, and the other with the tube at any distance below this plane.

The principles of this method may be understood from the drawing (Fig. 420), in

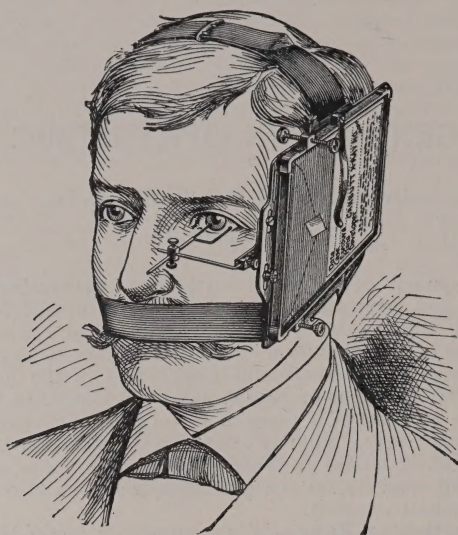


FIG. 421.—Indicating apparatus and plate-holder.

which a candle-flame is used to represent the X-ray tube. Rays of light coming from the candle when at *A*, in casting shadows upon a flat surface of two ball-pointed rods and an object in a sphere representing the eye, give the view as shown on the surface *C*.

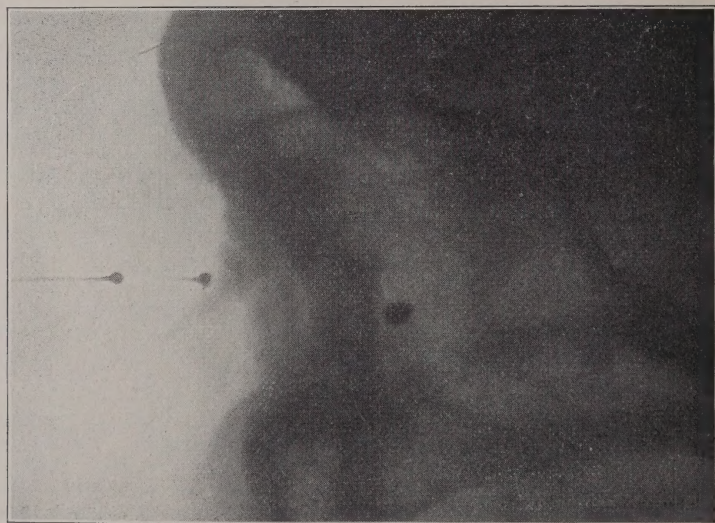


FIG. 422.—Radiograph made with the tube horizontal with the plane of indicators.

When the source of light is carried below the horizontal plane of the two rods to *B*, the shadows of the indicators take the position shown on the surface *D*, while the relative position of the body also changes. Knowing the distance of one of the balls from the center of the cornea and the distance between the balls, the position of the metal in the

eye may be readily determined, since the shadow of the body preserves at all times a fixed relation with respect to the shadows of the indicating balls in whatever position the candle is placed.

In practice it is essential that the axis of the eyeball shall be parallel with the two indicators and with the photographic plate; that one of the indicators points to the center of the cornea and be at a known distance therefrom; and that the two indicating balls be in a perpendicular line with the plate and at a known distance from each other. Simplicity has been secured by combining the plate-holder and indicators into a special apparatus which is bound to the side of the head, as shown in Fig. 421.

The determination of the position of a foreign body in the eye by the method described may be understood from the two radiographs which are reproduced in Figs. 422, 423. These were made of a man who was shot in the face by a rabbit-hunter, one of the shot penetrating at a point about 3 mm. below the superior border of the orbit of the

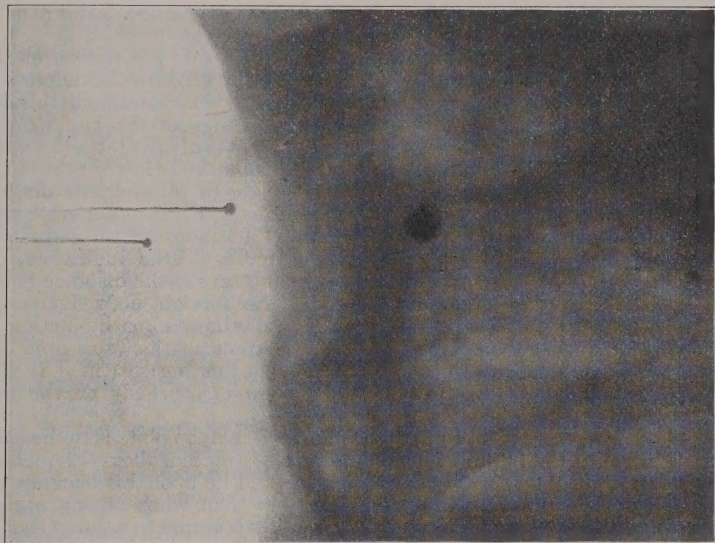


FIG. 423.—Radiograph made with tube below horizontal plane of indicators.

left side. No view of the fundus of the left eye was possible, owing to the denseness of the vitreous, although a slight red reflex was present in the upper portion of the eye.

In determining the position of the body in the eye two circles, 24 mm. in diameter, are drawn upon paper, one to represent a horizontal and the other a vertical section of the average adult eyeball. Upon these circles are noted the positions of the balls of the indicators when the exposures were made.

Measurements are made upon each of the radiographs of the distance that the shadow of the foreign body is above or below the shadows of the indicators, and these distances are entered above or below the spots representing the two indicating balls on the circle showing the vertical section of the eye. Lines drawn through the points of measurement from the two radiographs (*C* and *D* and *E* and *F*) indicate the plane of shadow of the foreign body at each exposure. Where the two lines cross, therefore, must be the location of the body as measured above or below the horizontal plane of the eyeball and to the temporal or nasal side.

The location of the foreign body back of the center of the cornea is determined by measuring the distance that the shadow of the body is posterior to the shadows of the two indicating balls on the radiograph made with the tube horizontal to the plane of the indicators, marking off the measurement perpendicular to each of the spots representing the indicators on the horizontal section of the eye, and drawing a line through these points. Since this represents the plane of shadow of the foreign body when the radiograph was made, the metal must be situated at some point on this line. The location of the body as respects the vertical section of the eyeball having been determined, where a line drawn perpendicular to this position intersects the plane of shadow on the horizontal section is the situation of the body back of the anterior portion of the eyeball. When the distance of the platinum plate of the tube from

the center indicating ball is known, the plane of shadow of the body on the horizontal section of the eye is determined by drawing a line directly from a point representing the tube to the spot of measurement of the shadow of the body back of the external indicator.

In order to render the various measurements clear, outline drawings of the two radiographs, reduced one-third in size, are shown in Figs. 425 and 426, the lettering corresponding to that employed on the diagrammatic circles.

When the photographic plate is in place at the side of the head, it is necessary in the majority of cases to arrange the point of fixation so that the cornea is rotated slightly inward, in order that the visual axis shall be parallel with the plane of the photographic plate. This rotation of the eyeball in no way affects the method of locating bodies within the globe, but when the body has penetrated into the orbit outside of the eyeball, the convergence necessary to ensure parallelism of the visual axis and the plate leads to error in the determination of the position of the metal. To eliminate this factor of error necessitates a knowledge of the angle of the orbit with the plate, or, what is equivalent, the amount of deviation of the eyeball from the primary position, and the employment of this angle in plotting the diagrammatic circles representing the eyeball. Another error arises from the false projection of the shadow of the body in the orbit in relation to the shadows of the indicators, owing to greater divergence of the rays as the distance between the center indicator and the foreign body increases. This false projection may be allowed for by noting the distance of the platinum plate of the tube from the center indicator, and employing this measurement in determining the plane of shadow of the body on the horizontal section of the eye.

In making the exposures the plate is to the side of the head corresponding to the injured eye, and the tube is placed about 12 inches to the opposite side and slightly forward. The patient should lie upon his back, as this position ensures greater steadiness of the head and body than when sitting upright with some form of head-rest. An exposure of four minutes is ample to secure clear shadows of bodies in the eyeball or orbit, and with efficient apparatus good radiographs may be secured in one-half this time. As the best results are achieved when the tube is run

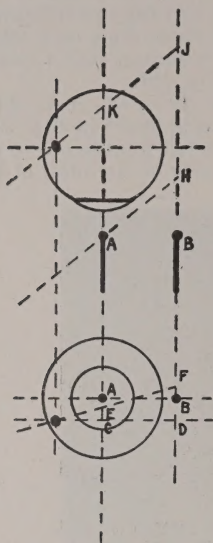


FIG. 424.—Diagrammatic circles representing the eyeball: upper circle, horizontal section; lower circle, vertical section (reduced one-third in size).

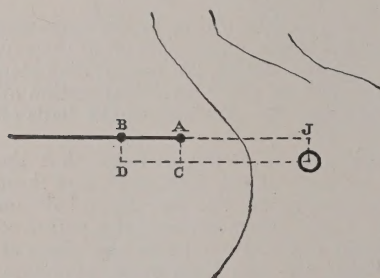


FIG. 425.—Outline drawing of radiograph made with tube horizontal with plane of indicators (reduced one-third in size).

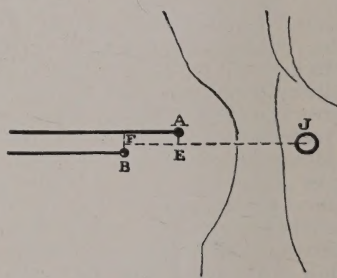


FIG. 426.—Outline drawing of radiograph made with tube below horizontal plane of indicators (reduced one-third in size).

at a high vacuum, a tube should be selected which may be so operated that the resistance offered to the passage of the current does not reach a point to interfere with the generation of the rays. The cathodal terminal should be ground and polished, so that the rays are focussed to a small point upon the platinum, which ensures sharper outlines of the foreign body than when the focus-point is large.

Accuracy of the Method.—It has been conclusively shown in actual work that the x-rays may be relied upon to determine in nearly every instance the presence or absence of a foreign body in the eye. The difficulties of shadowing the body on the plate increase with the smallness of the object, especially if it is situated to the nasal side of

the eye and therefore some distance from the sensitive surface. It is evident that cases may occasionally be seen where the body is so small as to fail to cast a shadow of sufficient distinctness to be recognized in comparison with the shadows of the orbital bones, although chips of metal which are too minute to be shown by the rays seldom strike the eye with sufficient force to overcome the resistance of the ocular structures and penetrate deeply into the globe. In cases of doubt as to the presence of a metal body in the eye, several exposures should be made with the tube in various positions, in order to cause the body, if present, to be shadowed through the thinnest portion of the orbital bones, and thereby exhibit sufficient contrast to assist in revealing its presence.

Dangers.—The introduction of more powerful apparatus for the generation of the rays has reduced to a minimum the dangers of severe injury of the superficial structures of the body by decreasing the time of exposure. Persons of fair complexion are particularly susceptible to the action of the rays, although a slight redness of the skin is all that may be expected in any case in the short period required in making the negatives. It is a safe plan, however, to limit the exposures at one sitting to four, which at the most would subject the patient to the action of the rays for a period of sixteen minutes. In this way it is possible to note the effect on the skin, and, if additional radiographs are desired, postpone the second sitting for several days in case marked redness follows the first exposures.

Influence on Vision of Blind Eyes.—The experiments made by Hansell,¹ by Wilkinson of the California School for the Blind, and by Hilgartner and Northrup conclusively show that the X-rays have no power whatever of exciting vision or even light perception in an eye, diseased or normal, and are without beneficial effect in the treatment of diseases leading to blindness. These investigations were made upon a number of patients who were blind from dense opacities of the cornea, congenital cataract, or complete optic atrophy.

THE PRACTICE OF OPHTHALMIC OPERATIONS ON ANIMALS' EYES.

By CLARENCE A. VEASEY, A. M., M. D.,

OF PHILADELPHIA.

Introduction.—The frequent practice of ophthalmic operations upon animals' eyes is of the greatest importance to the beginner in operative ophthalmology, as it enables him to become acquainted with the use of the various instruments, to recognize the difference in the density of the tissues which have to be cut, to become thoroughly familiar with the technic of each operation, and to lose a certain amount of the timidity which is almost invariably present when beginning operative work upon the human eye.

Instruments.—A set of instruments should be obtained and used for this purpose alone. The following are all which are required for practising most of the operations on the eyeball and muscles: An eye-speculum, a pair of fixation-forceps, an angular keratome, a v. Graefe cataract-knife, a pair of iris-forceps, a pair of iris-scissors, a cystotome and Daviel's scoop, a cataract-needle, a strabismus-hook, a pair of strabismus-scissors, a canaliculus-knife, a small scalpel, and a few curved needles.

Choice of Eyes.—Pigs' eyes are the most useful for practising the various operations. They more nearly resemble human eyes in size and density of tissue than do the eyes of other animals that are readily obtainable, and they can be easily fastened in the various masks. Sheep's eyes are too large for the latter purpose, and bullocks' eyes, while useful for demonstrations before a large class, possess tissues which are too dense and are themselves too large for the instruments which are commonly employed in operations on the human eye to make them of practical value.

For operations upon the muscles, the orbits, and the lids it is necessary to have a head with the eyes in their natural positions. For this purpose the head of a young pig, about six weeks old, is perhaps the easiest obtained and answers the purpose very well. The butcher must be cautioned, however, to allow the head to remain in scalding water for the shortest possible time preparatory to removing the bristles, or the eyes will be too shrunken to answer the purpose. Even with these precautions the corneas will be a trifle hazy, but if the eyeballs retain their firmness, this defect will not interfere with the subsequent practice of the operations.

¹ *Amer. Journ. of Med. Sciences*, Nov., 1897.

If possible, all the operations should also be practised upon the head of a cadaver; but, unfortunately, it is difficult to obtain material of this character outside of the dissecting-rooms of medical schools, and even when it is at hand the eyes are often so shrunk and collapsed, and have undergone such great changes, that it is fully as satisfactory, if not more so, to practise on the animal's eyes. To obtain correct ideas, however, of the topography of the parts practice on a cadaver as fresh and well preserved as possible is essential.

After practising for a time upon eyes placed in a mask and upon eyes in their natural positions in a pig's head, it is advisable to obtain some experience in operating upon the eyes of live animals. Dogs, cats, or rabbits may be used, the latter being perhaps the least expensive and most easily handled. The animals should be anesthetized with chloroform before operating, and at the conclusion of the operation the anesthesia should be pushed sufficiently far to produce death.

Time of Removal of Eyes from the Animal.—As eyes always undergo various changes shortly after death which render them less valuable for operative work, they should be removed from the animal as soon as it is killed. It is especially important that they be removed before the animal is scalded preparatory to scraping off the bristles, otherwise the corneas will become so opaque and shrunk as to render them useless.

Method of Preserving Eyes for Operating Purposes.—Fresh eyes are by far the best and most satisfactory for operative work. They impart to the hand a more natural sense of resistance of the tissues, and the corneas are much clearer than they can possibly be after preservation in any liquid. If it is impossible, however, to obtain them fresh when desired, they can be preserved for operating purposes for about one week by placing them in a $\frac{1}{10}$ of a 1 per cent. solution of formaldehyd. A stronger solution, though excellent as a preservative, hardens them too much for operative work. Should

it be desired to preserve them even longer, they may be transferred to a solution of thymol (1:5000), in which they will keep for several weeks (Andogsky). No matter whether fresh or preserved eyes are employed, the corneas will be found to be more or less dry, so that before beginning any operation they should be moistened with water.

The Operating Mask.—It is customary when practising operations upon animals' eyes to place the latter in masks especially constructed for the purpose. The best of these is the Viennese mask seen in Fig. 427. This represents a human face with most of its relations preserved, and in the orbital cavities are placed removable sockets in which the animal's eyes can be firmly held. These sockets permit the eyes to be moved in all directions, and by turning a central screw on which the eye rests the latter can be tightened or loosened, so that the intraocular tension may be decreased or diminished at will. The face is so attached to its base that it can be placed at different angles, and is made of hard rubber to prevent absorption of the various ocular fluids. Other masks known as "phantom faces" and made of *papier mâché* may be also used for the same purpose.

The Home-made Mask.—If the student does not possess the Viennese mask or a phantom face, a fairly satisfactory substitute may be constructed at home from a small box and a piece of cork. The latter should be sufficiently thick to enable the hand to move freely without striking the lid of the box, and is glued to the latter as shown in Fig. 428. An eye is readily

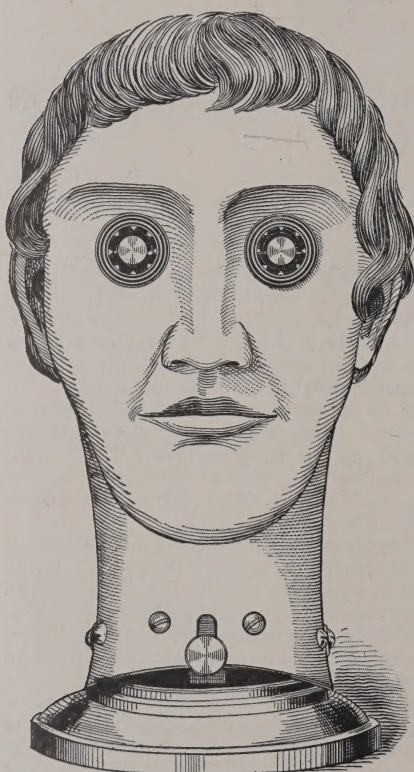


FIG. 427.—Vienna mask.

fastened to this by means of four tacks or stout pins, and the lid can be placed at any angle desired.

Should no mask be at hand, an eye can be wrapped in a towel and held in the hand

of an assistant, which rests firmly on a table while the different operations on the eyeball are being practised (Fig. 429). The greatest objection to this method is the impossibility of holding an eye firmly without making considerable pressure, which spoils, to a certain

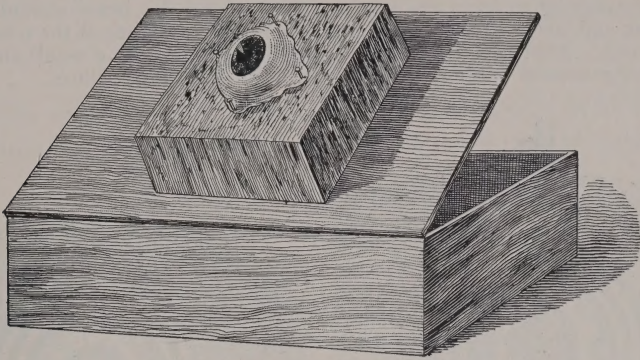


FIG. 428.—Home-made mask.

extent, most operative procedures. The method is of great value, however, in practising puncture and counter-puncture and the different varieties of corneal sections, and in these the assistant may be dispensed with, the eye being held in one hand while the knife is manipulated with the other.

Preparation of the Eye for the Mask.—When the eyes are removed from the pigs

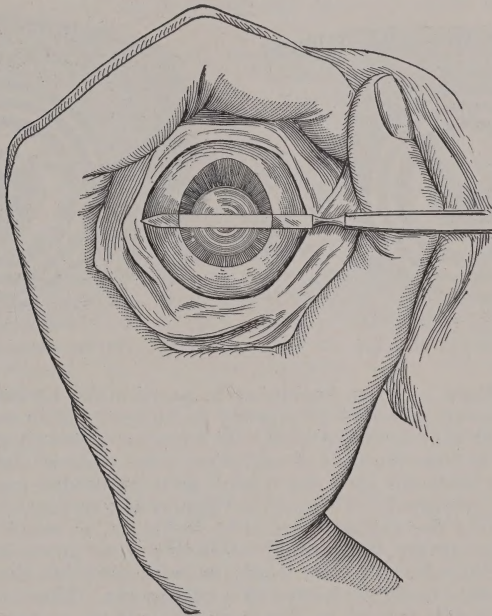


FIG. 429.—Eye in towel.

they have attached to them, as a rule, the stumps of the muscles, some conjunctiva, and more or less of the orbital fat. Enough of this should be trimmed off to enable the eye to fit easily into the socket of the mask, but at the same time care must be exercised not to remove too much or the eye cannot be held sufficiently tight for the satisfactory performance of an operation. A little practice will soon enable the student to know just how much tissue to remove, so that the strongest possible grasp may be maintained during the whole operation.

The shape of the pig's cornea differs somewhat from that of the human cornea, and in placing pigs' eyes in the mask-socket the round end should be turned upward. In this manner the shortest diameter of the eye is horizontal, and the iris is less apt to fall in front of the knife in making corneal sections than when placed in any other position.

Before attempting to fit an eye into the mask-socket the latter should be removed from the mask and the cavity made as large as possible by means of the screw on which the eye is to rest. After this an eye is placed in position, and a small circular metal band containing several teeth is pushed over it to hold it in place.

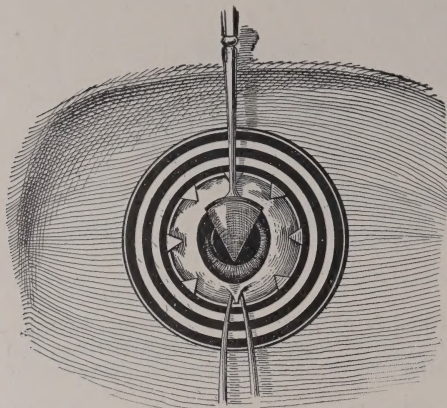


FIG. 430.—Position of the keratome in iridectomy.

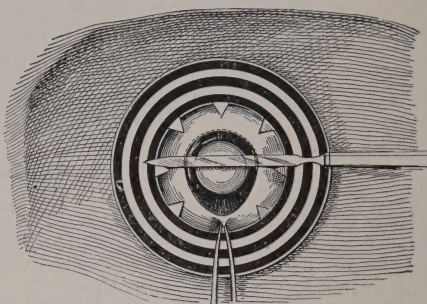


FIG. 431.—Cataract-knife making section.

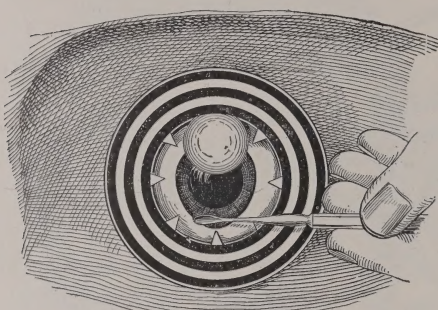


FIG. 432.—Delivery of the lens.

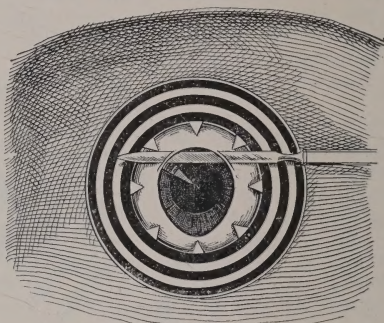


FIG. 433.—Anterior sclerotomy.

General Directions.—Before beginning to practise any operation the instruments required for that operation should be selected and placed within easy reaching-distance in the order in which they are to be used. If some one is assisting, the operator should not remove his eyes from the field of operation more than is absolutely required, the assistant placing in his hands each instrument as it is needed and removing the ones that have just been employed. The operator should also be careful to assume only such positions in relation to the animal's eye, or to the mask, as could be easily attained if operating on the human eye, and should studiously avoid any but the proper manner of holding the instruments. In other words, as much attention should be paid to detail as if the operation were being performed on a human eye. Thus only proper habits will be formed, for the habits formed in this work will adhere to the student in his later work upon human eyes, and, if they be incorrect, will be difficult to overcome.

Operations which can be Practised.—In general, most of the operations which are performed on the human eye may be practised on animals' eyes employed as previously described. Figs. 430–433¹ are sufficiently illustrative of some of the main operations.

¹ Taken from the author's work, *Ophthalmic Operations as Practised on Animals' Eyes*.

THE MOST IMPORTANT MICRO-ORGANISMS HAVING ETIOLOGICAL RELATIONSHIP TO OCULAR DISEASES.

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THE normal conjunctiva always contains bacteria, no less than ten or twelve varieties having been isolated. If these organisms have pathogenic characteristics they are very slight (Randolph); indeed, it is probable that only two or three varieties should be classified as at all pathogenic (Weeks). Non-pathogenic conjunctival bacteria, however, may become harmful if the tissues in which they exist are bruised or irritated (Randolph).

Pathogenic bacteria, especially those related to suppuration, are frequently found along the ciliary margins and in the secretion of the lachrymo-nasal passages.

The etiological relationship of micro-organisms to various ocular affections has been fully described, especially in the articles on Diseases of the Conjunctiva, Diseases of the Cornea, and Sympathetic Ophthalmitis. For the convenience of the student a brief description of these organisms, together with the stains by which they may be recognized, is here inserted.

Koch-Weeks' Bacillus.—According to Weeks, this bacillus resembles that of mouse-septicemia in form, and measures 1 to 2 μ in length and about 0.25 μ in thickness. It is often associated with a clubbed bacillus (*pseudo-diphtheritic* or *xerosis bacillus*). It stains readily with ordinary anilin dyes, and may easily be demonstrated in the secretion of affected eyes. (See Plate 2, Fig. III.)

As reagents Weeks uses methylene blue, basic fuchsin, or gentian violet.

This bacillus has been found by Weeks, Morax, Beach, and others to be the etiological factor in acute contagious conjunctivitis, as it is fully described on page 276.

Pneumococcus (*Diplococcus pneumoniae* (Weichselbaum); *Micrococcus Pasteuri* (Sternberg); *Micrococcus lanceolatus* (Talamon); *Fränkel's pneumococcus*).—This organism appears in the form of oval cocci each about 1 μ in its longest diameter. The cocci are often arranged in pairs (hence the name diplococci), and sometimes in chains of three to ten elements. The free ends of the cocci may be pointed (hence the name diplococcus lanceolatus), and they are often surrounded by a capsule (hence the term capsulated diplococcus). (See Plate 2, Fig. IV.) The organism stains with the ordinary anilin dyes, and also by Gram's method.

Pneumococci were first described as a cause of acute conjunctivitis by Morax and Parinaud, who supposed the disease was peculiar to early childhood. The later investigations of Gasperini, Harold Gifford, and others show that the affection is distinctly contagious, may attack adults, may be transferred from one eye to another, and may originate acute inflammation of the conjunctiva, clinically very difficult to differentiate from the Koch-Weeks' bacillus conjunctivitis (see also pages 275, 276).

According to the researches of Uhthoff and Axenfeld, which have been abundantly confirmed, pneumococci are the most important etiological factors in true serpiginous ulceration of the cornea (see page 314). They are also one of the causes of panophthalmitis.

Gonococcus (*Gonococcus of Neisser*; *Micrococcus gonorrhoea*; *Merismopedia gonorrhoea*).—This organism is found in gonorrheal pus, in the form of a micrococcus about 0.7 μ in its long and 0.5 μ in its short diameter. It often occurs in a diplococcus- and sometimes in a tetrads-form, the individual cocci being ovoid in shape, with their opposing surfaces flattened or slightly concave. The organism appears in characteristic groups within the leukocytes. (See Plate 2, Fig. II.; also Figs. 187 and 188). Gonococci stain readily with watery solutions of the basic anilin dyes—e. g. methylene blue, fuchsin, etc.—but are decolorized by Gram's method.

They are the etiological factor in gonorrheal conjunctivitis and in severe cases of conjunctivitis neonatorum (see pages 278, 281).

Klebs-Löffler Bacillus (*Bacillus diphtheriæ*; *Löffler's bacillus*).—This organism occurs in diphtheritic products as a slender bacillus, with round, occasionally distinctly clubbed ends, about $3\ \mu$ in length. The bacilli may be irregularly scattered, may appear in clusters, or may assume a parallel grouping; often two bacilli are joined end to end (see Fig. 190). The organism stains readily with the ordinary anilin dyes, by Gram's method, and, best of all, with Löffler's methylene blue. It is the cause of diphtheritic conjunctivitis (see page 284).

The *pseudo-diphtheritic bacillus* morphologically closely resembles the virulent bacillus diphtheriæ, but is not fatal to animals. It is found in several varieties of conjunctivitis—*e. g.* follicular conjunctivitis.

Xerosis Bacillus.—This organism was first found in xerosis of the conjunctiva, and morphologically, as well as in cultures, closely resembles the diphtheritic bacillus, but is non-virulent to animals (see also page 296). It is said to be present in the normal conjunctiva, and is found in a variety of conjunctival diseases, either alone, or, as in Koch-Weeks' bacillus conjunctivitis, associated with the specific organism.¹

Tubercle Bacillus (*Bacillus tuberculosis*; *Koch's tubercle bacillus*).—This organism occurs in tuberculous tissue or sputa, in the form of a slender rod with rounded or slightly curved ends 3 to $5\ \mu$ in length and $0.3\ \mu$ in breadth. Sometimes, when stained, the bacilli present a "beaded" appearance. In the tissue they are irregularly scattered or are arranged in small masses. They may be single, or an angle may be formed by an end-to-end attachment of two of them (see Fig. 201). Tubercle bacilli do not stain readily with ordinary watery solution of basic anilin dyes; anilin-water solution of gentian violet or fuchsin must be used. One of the best preparations is the Ziehl-Neelsen carbol-fuchsin. Once stained, the bacilli retain the dye tenaciously. They are the cause of tuberculous lesions in the ocular coats (see page 302).

Leprosy Bacillus (*Bacillus lepræ*).—This organism occurs in the leprous tubercles, in the form of a bacillus which closely resembles the tubercle bacillus, but is slightly more slender (Fig. 200). The bacilli stain readily with the ordinary anilin dyes and by Gram's method.

Staphylococcus Pyogenes Aureus (*Micrococcus pyogenes aureus*).—This organism is one of the bacteria of suppuration, and occurs as a spherical coccus from 0.5 to $0.9\ \mu$ in diameter, and grows in clusters and masses, but is also met with singly and in pairs (see Fig. 192). It stains readily with all the anilin dyes, and also by Gram's method.

Staphylococci are related to numerous inflammatory conditions of the cornea and conjunctiva, being found, for example, on the ciliary margins in blepharitis, in phlyctenular conjunctivitis, in simple conjunctivitis, and in association with specific organisms—for instance, with Löffler's bacillus in diphtheria of the conjunctiva, and with gonococci in gonorrheal conjunctivitis. They are freely present in suppurative conditions of the lachrymo-nasal passages, are one of the varieties of micro-organisms found in mixed infections in corneal ulcers which are not typically seriginous, and have been claimed by Deutschmann to be the cause of sympathetic, or, as he called it, migratory ophthalmitis (see page 349). In addition to staphylococcus pyogenes aureus may also be found the varieties which are known as *S. pyogenes albus* and *S. pyogenes citreus*, which differ from the preceding organism in the color of their growth, as is designated in the name. They are also said to be less pathogenic than the first one.

Streptococcus Pyogenes.—This organism occurs as a coccus slightly larger than the preceding varieties, being about $1\ \mu$ in diameter. It forms chains (see Fig. 197) which sometimes are composed of numerous members. It may be demonstrated by the usual stains.

Streptococci are found in various suppurative processes which occur in the eye, either alone or in association with specific micro-organisms, and they are the cause of certain varieties of corneal ulcers. They are especially frequent in the purulent secretion which comes from the lachrymal sac, being the cause of the conjunctivitis which is associated with this condition. This form of conjunctivitis may also be complicated, according to Parinaud, with hypopyon and irido-cyclitis (see also page 294).

There is one variety of *membranous conjunctivitis* due to streptococci which occurs

¹ The terms "*pseudo-diphtheritic bacillus*" and "*xerosis bacillus*" have been much confused, because the *pseudo-diphtheritic bacilli* of Hoffmann, which are found in the nose and throat, are not identical with the *pseudo-diphtheritic bacilli* of the conjunctiva, which, by some authorities, are made to include the xerosis bacilli, the bacilli septati (Gelpke), the chalazion-bacilli (Deyl), etc.

The investigations of D. H. Bergey indicate that there is a large group of micro-organisms, at the head of which is the *virulent Löffler-bacillus*, which may occur in several distinct variations, and at the other extreme is the *xerosis bacillus*. Between these extremes are many variations in type, as shown by modifications in biological and morphological characters, for example, the pseudo-diphtheritic or Hoffmann's bacilli.

in children in connection with the exanthemata, but which, according to Morax, may appear independently of febrile complications. The disease is often mistaken for diphtheritic conjunctivitis, and is sometimes called "*streptococcus diphtheria of the conjunctiva*." Microscopic examination will decide the diagnosis. The prognosis is exceedingly unfavorable.

In this connection a brief mention of a remarkable form of conjunctivitis, known as *Parinaud's conjunctivitis* or *infectious conjunctivitis of animal origin*, may be made. Its main characteristics, as summarized by Gifford, who has studied it in this country, are sudden onset, thickening of the lids, mucopurulent discharge, the formation within a week or two of large polypoid and pediculated granulations on the conjunctiva, between which occur numerous smaller yellowish ones, and inflammation of one or both of the groups of lymph-glands on the same side, the pre-auricular and retromaxillary groups being most frequently involved. The affection is practically always one-sided. Bacteriological investigations have generally been lacking in results, but streptococci have been found in the pus in the eye and in the inflamed lachrymal glands. The treatment suited to trachoma would seem to be indicated.

Trachoma Coccus.—This organism has been described by Sattler and Michel, and may be cultivated from the trachoma follicle. It forms a small diplococcus (Fig. 195). Its specificity has not been demonstrated (see page 292).

Diplo-bacillus (*diplo-bacillus of Morax and Axenfeld*).—This organism was first described by Morax in 1896 as a frequent cause of subacute or chronic conjunctivitis.



FIG. 433 a.—The diplo-bacillus of Morax and Axenfeld (from a preparation by Dr. Harold Gifford).

According to Harold Gifford, who has investigated it in this country, "the germ commonly occurs in the form of a diplo-bacillus, each member of which measures 2 to 3 μ in length and 1 to 0.5 μ in breadth. Chains of these diplo-bacilli are not infrequent, and, in cultures, form sometimes as long as three or four of the single bacilli with no apparent sign of division." It stains readily with most of the ordinary dyes, but is decolorized by Gram's method.

The conjunctival affection which this diplo-bacillus causes in general is insidious in character. It runs a course of from six weeks to six months, during which the main symptoms are slight redness and hypersecretion of the conjunctiva with moderate subjective symptoms. Often the only sign of its presence is a persisting agglutination of the lids in the early morning. The secretion of stubborn subacute conjunctivitis should always be examined for this bacillus. The best local application for relief of *diplo-bacillus conjunctivitis* is a $\frac{1}{2}$ per cent. solution of chlorid of zinc. According to Gifford, diplo-bacilli may also originate a condition closely resembling subacute trachoma, and sometimes they are the active organisms in corneal ulcers.

The relation of micro-organisms to infective or sloughing ulcers of the cornea has been briefly referred to several times in the preceding paragraphs, and the most important bacteria described. Unthoff and Axenfeld thus summarize our knowledge on this subject:

(1) Typically serpiginous ulcer of the cornea with hypopyon is practically always caused by the pneumococcus, which may frequently be found in these ulcers in almost pure cultures.

(2) Ulcers not typically serpiginous are caused by infection with staphylococci and streptococci and by mixed infection. Occasionally, pneumococci originate ulcers which are not characteristically creeping.

(3) About one per cent. of sloughing varieties of keratitis is due to a schizomycetal infection—*aspergillus fumigatus*.

The following organisms have also been found at times in association with keratitis: *Pfeiffer's capsulated bacillus*, *Bacillus pyogenes fetidus*, *Bacterium coli*, *Bacillus pyocyaneus*, *Ozena bacillus*, and a number of other varieties which have not again been discovered or which could not be identified.

It is interesting to observe that in general suppurative inflammation of the entire eyeball (panophthalmitis), although the ordinary bacteria of suppuration may be present, not infrequently there are found special forms of bacilli.

It would be manifestly out of place to describe in detail bacteriological examinations (which are essential in all carefully-studied inflammatory affections of the conjunctiva and cornea) in this place; but for the convenience of the reader the formulæ of a few of the stains to which reference has been made are appended. These formulæ (with one exception) have been taken from Hewlett's admirable *Manual of Bacteriology*, which has been frequently consulted in the preparation of this section.

Löffler's alkaline methylene blue.

Concentrated solution of methylene blue,	30 c.c.;
Solution of caustic potash, 0.01 per cent.,	100 c.c.
This will stain cover-glass specimens in from three to ten minutes.	

Anilin gentian-violet.

Saturated alkaline solution of gentian violet,	30 c.c.;
Anilin-water,	100 c.c.
This preparation will stain cover-glass specimens in two or three minutes.	

Carbol-fuchsin (Ziehl-Neelsen solution).

Fuchsin,	1 part;
Absolute alcohol,	10 parts;
Five per cent. aqueous solution of carbolic acid,	100 parts.
It should be diluted with 2 to 6 parts of water for cover-glass specimens.	

In Gram's method the cover-glass specimens are stained for five or ten minutes in anilin gentian-violet solution, and then immersed for one or two minutes in a solution of iodine 1 part, potassium iodide 2 parts, distilled water 300 parts. When the specimens are removed from the iodine solution and drained, they are immersed in methylated spirit. After decolorizing, the specimen may be washed in water, dried, and mounted.

E. A. de Schweinitz's method for staining tubercle-bacilli with Sudan iii. (red-fat dye) is a selective one. A saturated alcoholic solution is used. This preparation, made in the ordinary way, is stained for five minutes in this solution and washed with 70 per cent. alcohol.

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